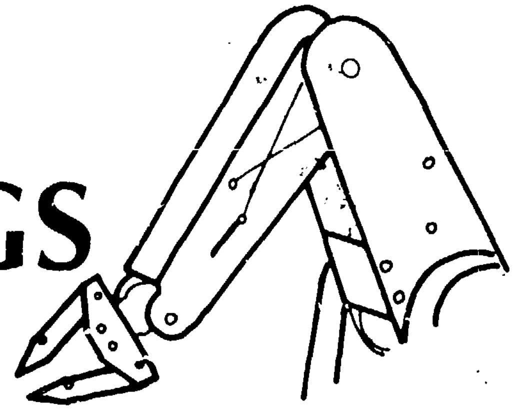
DOD ROBOTICS APPLICATION WORKSHOP

PROCEEDINGS



4 - 7 OCTOBER 1983

Sierra Inn
Sacramento, CA

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

(TITLE): DoD Robotics Application Workshop Proceedings Held at Sacramento, California on 4-7 October 1983.

(SOURCE): Defense Systems Management College, Fort Belvoir, VA

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P003 998	Current Successful Robotics Applications by the Automatix Company.
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AD-P004 001	Air Force Landing Gear Repair - Ogden Air Logistics Center Industrial Products and Landing Gear Division.
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AD-P004 008	Depot Modernization at the Defense Logistics Agency
AD-P004 009	aser Paint Removal. ~~at the Air Force Logistics Center,~~
AD-P004 010	Air Force Materials Laboratory Plans/Projects.
AD-P004 011	Future Robotics Program at San Antonio (Air Logistics Center) ~~Resources Management Division~~. AAC
AD-P004 012	Robotics in Nondestructive Inspection at Sacramento Air Logistics Center.
AD-P004 013	Shipyard Automation, Robotics Applications and Plans; Naval Sea Systems Command.
AD-P004 014	Supply Center Processes.
AD-P004 015	Potential Application of Robotics and State-of-the-Art End Effectors at Letterkenny Army Depot.

COMPONENT PART NOTICE (CON'T)

AD#: P004 016 **TITLE:** Field Applications for Robotic Materiel Handling. ~~at Tooele Army Depot~~.

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FOREWORD

The proceedings of the DOD Robotics Applications Workshop contain presentations and summaries of material offered at the workshop. There were 74 formal day presentations, eight roundtable summary presentations, and ten evening presentations offered in the three-day workshop period; in all, more than 46 hours of presentations and discussion.

Not all speakers offered hard copy material of presentation graphics. However, all formal day sessions were audiotaped. Thus, wherever hard copy was not provided, a brief summary of what was offered has been reconstructed from the corresponding audiotape and included in the proceedings. The material submitted by the presenters has generally been reproduced as received, except where the graphic quality of the submittal mandated that minor typing or enhancement be effected to assure reproducibility.

The proceedings are organized to follow the flow of the workshop. An Executive Summary is provided and includes: (1) material on the DOD organic industrial base and its operations and processes; (2) a listing of current major DOD industrial robotics projects; and (3) the menus of needs, issues, and project ideas developed by the eight roundtables for the ten technical topic areas. The roundtable menus constitute the primary product of the workshop.

Following the Executive Summary is introductory material describing the genesis of the workshop and its organization. Abstracts of private sector expert briefs and the operations and processes briefs of DOD activities, material offered by DOD activities on current robotics projects, plans for the future, and the balance of the DOD current projects/future plans material constitute the program portion of the proceedings. Bon appetit!

EXECUTIVE SUMMARY

The DOD Robotics Applications Workshop was held October 4-7, 1983 at the Sierra Inn, Sacramento, California. The event was co-hosted by the Air Force Sacramento Air Logistics Center and the Sacramento chapter of the Society of Logistics Engineers (SOLE). The workshop brought together for the first time private sector experts and engineering and senior management representatives from all the industrial activities of the three services save one (Norfolk Naval Shipyard) to focus on a leading edge industrial technology. This had never been done before. More than two hundred attendees (180 + formal registrants) from army depots and arsenals, navy shipyards, air rework facilities, weapons stations and ordnance activities, supply centers, public work centers, air force logistics centers, the Defense Logistics Agency, DOD, etc., received briefs on the state-of-the-art, current practice, successful implementations, and current research and research directions in robotics from 13 private sector experts chosen by the Robot Institute of America (RIA).

Next, attendees selected by the represented DOD Industrial activities presented the industrial processes and process economics of their industrial operations to the audience. Current robotics projects and project plans for robotics and automation for both the near term and the future were also offered by the attending DOD activities.

Finally, the resultant elevated knowledge base and collective expertise of both the private sector and public sector attendees were applied in three dimensions (current applications, technology transfer/manufacturing technology needs, and research issues and needs) in ten technical topic areas by eight groups of attendees in a unique brainstorming roundtable format. The result was a knowledgeably ranked menu of potential robotics-related investments which represent an extraordinary and stunning opportunity to enhance the productivity, performance, and capability of the Department of Defense organic industrial base over the next decade.

The ten robotics-related technical areas addressed were: (1) Applications; (2) Installation/Design Concepts; (3) Safety and Security; (4) Languages; (5) Controls and Integrated Systems; (6) Mechanical Systems and Precision Operations; (7) Vision Systems; (8) Hands and End Effectors; (9) Sensors; and (10) Transportability/Mobility. That robotics is a systems issue embedded in an automation framework is most apparent because the roundtable-developed menus in these ten technical areas show considerable interaction and overlap. However, a remarkable range of distinct applications, needs, and potential project investments emerged in each technical area, many of which were unique and did not overlap the concepts developed in other roundtables. Each workshop participant was afforded the opportunity to participate in three roundtables of choice, and thus each technical area was brainstormed, discussed and the resultant product rated by three different groups of DOD participants utilizing for each iteration the same private sector expert as leader/facilitator.

Following this narrative is a workshop summary which outlines the needs, issues, and priorities developed by workshop attendees in each of the aforementioned technical areas. The summary is in essence an investment planning guide in robotics and automation systems for the entire DOD in-house industrial base, and should prove to be a valuable resource not only to DOD technology and capital investment planners but also to the robotics industry and academia as they attempt to assess and plan product development, research, and technology transfer (mantech) needs and priorities in support of the DOD organic industrial base.

CONCLUSIONS

- ROBOTICS IS A SEMINAL DEPOT TECHNOLOGY
- IDEAL ENVIRONMENT: LABOR INTENSIVE BUSINESS
- BROADEST POSSIBLE ROBOTICS APPLICATION PANORAMA
- EXTRAORDINARY POTENTIAL EXISTS FOR CURRENT IMPLEMENTATIONS
- MANY MANTECH PROJECT OPPORTUNITIES
- MUCH BUSINESS-SPECIFIC R&D NEEDED
- HEAVY SPILLOVER TO PRIVATE SECTOR APPLICATIONS
- NEW ECONOMIC MODELS NEEDED FOR SMART AUTOMATION INVESTMENTS
- INVESTMENT PLAN INTEGRATED WITH OVERALL MODERNIZATION/AUTOMATION OBJECTIVES NEEDED
- DEPOT PROCESS ARCHITECTURE MODEL NEEDED
- ROBOTICS IS A SYSTEMS ISSUE (AN EMBEDDED TECHNOLOGY)
- GENERIC APPROACHES TO INTEGRATION OF PROCESS, INTERFACES, ROBOTICS NEEDED

RECOMMENDATIONS

- o AGGRESSIVELY PURSUE CURRENT INVESTMENT OPPORTUNITIES
- o DEVELOP NEW ECONOMIC JUSTIFICATION MODEL (A LA IBM)
- o DEVELOP COORDINATED TRI-SERVICE ROBOTICS R&D AND MANTECH PLAN
- o AGGRESSIVELY PURSUE ROBOTICS MANTECH INITIATIVES
- o DEVELOP DOD ROBOTICS R&D PROGRAM ELEMENT
- o FUND DOD ROBOTICS R&D INVESTMENT LINE FOR TRI-SERVICE COMPETITION
- o CONSIDER ROBOTICS AS COMPONENT OF OVERALL OVERHAUL, REPAIR, REMANUFACTURING SYSTEM (CIM)
- o INITIATE PROJECT TO MODEL ARCHTYPE OVERHAUL, REPAIR, REMANUFACTURING ARCHITECTURE (HIERARCHICAL CONTROL)
- o INITIATE DECADE-LONG PLAN TO IMPLEMENT HIERACHICAL CONTROL AUTOMATION ARCHITECTURE IN DOD DEPOTS
- o SOLICIT/INVOKE SUPPORT OF THE CONGRESS FOR JOINT INDUSTRY/ACADEMIA/DOD ROBOTICS/AUTOMATION INVESTMENT ALLIANCE
- o USE DOD ROBOTICS WORKSHOP PROCEEDINGS AS REFERENCE PLANNING GUIDE FOR DOD ROBOTICS PROGRAM

THE PRODUCTS

- o TACTICAL VEHICLES
- o AIRCRAFT
- o SHIPS
- o WEAPONS SYSTEMS
- o ORDNANCE AND ORDNANCE SYSTEMS
- o SUPPORT EQUIPMENT AND SYSTEMS
- o SPARES AND PIECE PARTS
- o TECHNICAL SERVICES AND DATA
- o COMMUNICATIONS/ELECTRONICS
- o SUPPLY INVENTORY/PERSONNEL ASSETS
- o MISSILES

THE ORGANIZATION

- o PROCUREMENT/SUPPLY
- o PRODUCTION PLANNING AND CONTROL
- o TRANSPORTATION
- o PRODUCTION
- o ENGINEERING
- o QUALITY ASSURANCE
- o FINANCIAL AND COMPTROLLER
- o ADMINISTRATIVE SERVICES
- o TEST AND SELLOFF
- o PACKAGING AND PRESERVATION
- o MEASUREMENT AND STANDARDS

THE DOD ORGANIC INDUSTRIAL BASE

- o AIR INDUSTRIAL ACTIVITIES
- o PRODUCTION ARSENALS
- o PRODUCT LINE DEPOTS
- o SHIPYARDS
- o WEAPONS STATIONS/ORDANCE ACTIVITIES
- o SUPPLY CENTERS
- o MAINTENANCE/PUBLICK WORKS CENTERS
- o LABORATORIES WITH PRODUCTION/SUPPORT OPERATIONS

THE BUSINESS

- o VOLUME: $10B/YEAR
- o OVERHAUL
- o REPAIR
- o REMANUFACTURING
- o MANUFACTURING (ORDNANCE)
- o ENGINEERING/TECHNICAL SERVICES
- o SUPPLY SUPPORT
- o FACILITY MAINTENANCE AND SUPPORT

TYPICAL DOD DEPOT PROCESSES

- MATERIAL HANDLING/STORAGE
- MATERIAL TRANSFER/LOADING/UNLOADING
- PALLETIZING
- MACHINE LOADING
- FORGING
- DIE CASTING
- INVESTMENT CASTING
- MOLDING
- METAL FABRICATION/MACHINING
- DISASSEMBLY
- ASSEMBLY
- CIRCUIT BOARD HANDLING
- ELECTRONIC COMPONENT INSERTION
- WIRE HARNESS MANUFACTURE
- DRILLING/ROUTING
- CUTTING/BURNING
- TESTING, MECHANICAL
- TESTING, ELECTRONIC
- WELDING
- JOINING
- PAINTING
- COATING
- FACING/HARDENING/TREATING
- INSPECTION
- PACKAGING
- MATERIAL APPLICATION
- COMPOSITE LAYOUT
- DELIVERY
- SORTING
- CLEANING
- SECURITY
- TOOL CONTROL
- ANTHROPOMORPHIC EQUIPMENT OPERATION
- OTHER

CURRENT/PLANNED DEPOT ROBOTICS PROJECTS

PROJECT	SERVICE
TURBINE BLADE REPAIR	AIR FORCE
PLASMA SPRAY	AIR FORCE
FINISHING	AIR FORCE
HONEYCOMB SHAPING	AIR FORCE
SAND BLASTING/CLEANING	AIR FORCE
REAL TIME X-RAY	AIR FORCE
LASER PAINT REMOVAL	AIR FORCE/NAVY
ROBOTIC PAINTING	AIR FORCE/NAVY/ARMY
RIVETING/DERIVETING	NAVY
WIRE HARNESS MANUFACTURE	NAVY
NEUTRON RADIOGRAPHY INSPECTION	NAVY
SEAM WELDING/CUTTING	NAVY
SMALL STRUCTURE WELDING	NAVY/ARMY
VEHICLE SUSPENSION/TRACK DISASSEMBLY	ARMY
SHELTER REFINISHING	ARMY
VAN ASSEMBLY	ARMY
HAZARDOUS MATERIALS HANDLING	ARMY

ROUNDTABLE TOPICS

- APPLICATIONS
- INSTALLATION/DESIGN CONCEPTS
- SAFETY AND SECURITY
- LANGUAGES
- CONTROLS AND INTEGRATED SYSTEMS
- MECHANICAL SYSTEMS/PRECISION OPERATIONS
- VISION SYSTEMS
- HANDS AND END EFFECTORS
- SENSORS
- TRANSPORTABILITY/MOBILITY

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APPLICATIONS - SESSIONS 1 & 2

1. PAINT/DEPAINT
2. INSPECTION
3. X-RAY INSPECTION
4. MIG/TIG LASER WELDING
5. RIVET/DERIVET
6. ASSEMBLY/DISASSEMBLY
7. WIRE HARNESS ASSEMBLY
8. FIRE FIGHTING
9. COMPOSITE LAY-UP
10. GUN LOADING

UNRANKED APPLICATIONS - SESSIONS 1 & 2

- STENCILING, MARKING
- SHOT PEENING
- DEBURRING
- CLEANING
- MIXING
- BOX FABRICATION
- WATER JET CUTTING
- PACKAGING

APPLICATIONS - SESSION 3

1. PAINT/DEPAINT
2. GRIT BLAST
3. DEMENSIONAL INSPECTION
4. X-RAY INSPECTION
5. MIG/TIG, LASER WELDING
6. RIVET/DERIVET
7. ASSEMBLY/DISASSEMBLY
8. THERMO/PLASMA SPRAY
9. CALIBRATION/TEST
10. PACK, DEPACK, PALLETIZING

APPLICATIONS - GENERAL COMMENTS

- ECONOMIC JUSTIFICATION DIFFICULT
  - ANS: MULTIPLE USE/APPLICATIONS
- ELECTRONIC REPAIR - UNIVERSAL ROBOTICS NEED
- ROBOTICS PRECISION PARTS HANDLING -UNIVERSAL NEED
- PARTS DESIGNED FOR AUTOMATION -UNIVERSAL NEED
- HIGH MOBILITY ROBOTICS - UNIVERSAL NEED

INSTALLATION/DESIGN CONCEPTS AND SAFETY/SECURITY

- VENDOR CHOICE CRITERIA
- PRE AND POST INSTALLATION TRAINING
- INTERFACE WITH OLDER EQUIPMENT
- HUMAN FACTORS
- CRITERIA FOR TURN KEY SYSTEMS
- FEEDING MECHANISMS TO ROBOT
- ROBOT LAY-OUT
- ROBOT SERVICE, LIFE-HOSTILE ENVIRONMENT
- CAD/CAM, ATE, INSPECTION INTERFACE
- FLEXIBILITY FOR SMALL BATCH
- ADVANCE SENSOR INTERFACING
- WAREHOUSING AUTOMATION
- EXPLOSION PROOFING
- MOBILITY, POWER
- NEW MECHANICAL ROBOT DESIGN
- SENSOR INTERFACING
- HUMAN SAFETY
- PART/MACHINE SAFETY
- PAINTING/STRIPPING CELL--SMALL PARTS
- SYSTEM MAINTAINABILITY
- DERIVETING
- MULTI-USE SYSTEMS
- LOW VOLUME INSPECTION

INSTALLATION/DESIGN CONCEPTS AND SAFETY/SECURITY (CON'T)

- FUEL/MANIFOLD ASSEMBLY
- LARGE PAINTING/STRIPPING CELL
- ROBOT SYSTEMS APPROACHES
- PLATING CELL
- BRAKE SHOE CELL
- FOAM-IN-PLACE PACKAGING
- VEHICLE/TRUCK ASSEMBLY
- MANUFACTURING OF WOOD SHIPPING CONTAINERS
- BEARING INSPECTION/MATCHING
- BLACK AND VANE CELL SYSTEM
- ROBOTIC INTERIOR/CONTAINER COATING
- KITTING
- CIRCUIT BOARD TESTING/REPAIR SYSTEMS
- SURFACE MEASUREMENT
- SMALL SHIPBOARD ROBOTICS SYSTEMS
- SYSTEMS CONTROL INTERFACES
- GUIDELINES FOR SYSTEMS SPECIFICATIONS
- ROBOTICS SECURITY/SAFETY DESIGN CONCEPTS
- INTEGRATED SYSTEM DESIGN: MIS, FMS, CIM
- SOLDER/DESOLDER SYSTEM
- OPERATING ENVIRONMENT SPECIFICATION
- AUTOMATED NDI/TEST
- PIPE PREP, WELD, NDT
- INTERIOR TANK PORTABLE SERVICE ROBOTICS
- CO-ORDINATED MULTI-ARM ROBOT SYSTEMS
- STANDARDIZED SOFTWARE

LANGUAGES, CONTROLS, INTEGRATED SYSTEMS
PROCESS - TECHNOLOGY MATCHES

1. LOAD MACHINE WITH MOVING TURNTABLE (EXPLOSIVE)
2. ADAPTIVE PROCESS APPLICATIONS (WELDING, PAINTING, GRINDING)
3. MOVE BOXES WITH VARIABLE DIMENSIONS
4. ENGINE PARTS PAINTING
5. ENGINE PARTS INSPECTION
6. GAUGE BLOCK CALIBRATION
7. MACHINE TENDING -NC CELLS
8. BLASTING OF SIMPLE SURFACES
9. PAINTING SIMPLE PREDICTABLE GEOMETRIES
10. BEARING INSPECTION - SIMPLE ACCEPTANCE CRITERIA
11. INSTRUMENT SOLDERING AND DESOLDERING - SIMPLE

MANUFACTURING TECHNOLOGY NEEDS

1. MOVE BOXES WITH HIGHLY VARIABLE DIMENSIONS
2. DISASSEMBLY OF SIMPLE ELECTRONICS PACKAGES/DEVICES
3. BLASTING OF IRREGULAR SURFACES WITH CONSTRAINTS (AVOID NAME PLATES)
4. DISASSEMBLY AND CLEANING OF FUEL MANIFOLD NOZZLES
5. PAINTING COMPLEX SURFACES, COLORS, PATTERNS
6. BEARING INSPECTION AND CLEANING - MULTIPLE ACCEPTANCE CRITERIA
7. INSTRUMENT SOLDERING AND DESOLDERING - COMPLEX
8. WHOLE AIRCRAFT PAINTING/MARKING
9. SURFACE INSPECTION AND DEFECT MARKING
10. REPAIR OF COMPOSITES
11. INTEGRATED INSPECTION, DATA STORAGE SYSTEM
12. NEUTRON RADIOGRAPHY - CONTROLS
13. LASER PAINT STRIPPING - CONTROLS
14. CONFORMAL COATING REMOVAL
15. CONTROL/PROGRAMMING FOR LOW VOLUME PLASMA COATING
16. INTEGRATION OF COMPLEX SENSORS AND VISION WITH ROBOT CONTROL
17. STANDARDIZED PROGRAMMING TECHNOLOGY
18. INTEGRATED CAD/CAM DATA - ROBOTICS SYSTEMS
19. GROUP TECHNOLOGY - PROCESS PLANNING DATA INTEGRATION
20. STANDARD INTERFACES TO SENSORS, DATA BASES, ETC.
21. SMALL PARTS NDI
22. GENERAL PURPOSE CIRCUIT BOARD SCREENING

LANGUAGES, CONTROLS, INTEGRATED SYSTEMS (CON'T)
R&D NEEDS

1. DISASSEMBLY OF COMPLEX PACKAGES/DEVICES
2. ASRS BIN/ EM PICKING
3. SHEET METAL FABRICATION, CUTTING, BENDING VIA CAD/CAM LINKS
4. WHOLE AIRCRAFT PAINTING/DEPAINTING
5. MAN-MACHINE GENERIC CONTROL SYSTEM FOR FIELD APPLICATIONS
6. COMPOSITES REPAIR
7. INTEGRATED INSPECTION DATA/MACHINE TOOL DRIVER SYSTEM
8. INTEGRATION OF ROBOT VISION WITH CONTROL
9. TASK PROGRAMMING WITH MAN-MACHINE INTERFACE (SHOP FLOOR)
10. FUNCTIONAL PROGRAMMING
11. GROUP TECHNOLOGY INTERFACE
12. CO-ORDINATED CONTROL OF MULTIPLE ROBOTIC DEVICES

SUMMARY R&D NEEDS

- REQUIREMENTS DEFINITION AND STANDARD PROGRAM METHODOLOGY
- COMMUNICATION STANDARDS BETWEEN ROBOT CONTROL AND SUPERVISORY CONTROL (STD. INTERFACES)
- THREE DIMENSIONAL IGES DEVELOPMENT

MECHANICAL SYSTEMS/PRECISION OPERATIONS

NEED/OPERATION	----RATINGS---- ROI VALUE	MANTECH AVAILABILITY	R&D LEVEL REQUIRED (AVAIL)
PRECISION WELDING AND GRINDING (TURBINE BLADES)	3	1	10(0)
PRECISION INSPECTION AND QUALITY MEASUREMENT	2	2	6(4)
PRECISION DRILLING OF STRUCTURES	4	5	9(1)
DERIVITING/RIVETING	5	6	8(2)
MECHANICAL ASSY/DISASSY	1	4	1(9)
HAZARDOUS OPERATIONS/MUNITIONS	6	3	5(5)
PRECISION ROUTING/TRIMMING (AIRFRAME SURFACE PANELS)	7	8	7(3)
SURFACE PATCHING FOR COMPOSITE STRUCTURES AND HONEYCOMB PANELS	9	7	4(6)
AVIONICS/ELECTRONICS MODULE MAINTENANCE	8	9	3(7)
NUCLEAR REACTOR MAINTENANCE	10	10	2(8)

VISION SYSTEMS

APPLICATIONS

- RECEIVING-BOX SIZE
- INVENTORY
- SEWER INSPECTION
- SEAM TRACKING-IRREGULAR SHAPES - ALUMINUM
- SMALL PARTS INSPECTION
- AIRCRAFT SURFACE INSPECTION
- SMALL PARTS ASSEMBLY
- PART MEASUREMENT
- PACKAGING
- PROFILE
- PALLETIZING
- LOAD/UNLOAD CAROUSEL CONVEYORS
- PARTS/DIMENSION REPLICATION
- ORDER PICKING
- LARGE PART LOCATION AND SUBFEATURES
- BAR CODE LOCATION/OPERATIONS
- BIN PICKING
- PC BOARD INSPECTION
- COLOR IDENTIFICATION

VISION SYSTEMS (CON'T)

MANTECH NEEDS

- o INSPECTION OF VERY LARGE OBJECTS
- o CONTINUOUS WELDING
- o SMALL COMPONENTS INSPECTION
- o DERIVETING/FASTENER REMOVAL
- o TOOL GUIDANCE
- o FASTENER LOCATION
- o WEAPON LOADING
- o FIRE FIGHTING
- o AIRCRAFT COMPONENT ASSEMBLY
- o GMA WELDING
- o REAL TIME VISUAL DATA ACQUISITION
- o PART IDENTIFICATION

VISION SYSTEMS (CON'T)

R&D NEEDS

- o SORTING (COMPLEX GEOMETRIES)
- o WELDING
- o FASTENER IDENTIFICATION
- o CONTOUR FOLLOWING (FOR PAINTING, CORE REPAIR)
- o INSPECTION FOR DISASSEMBLY/ASSEMBLY
- o PRECISION INSPECTION
- o MACHINE LOADING
- o LOADING - TOOL CHANGING
- o BAR CODE OPERATIONS
- o SURFACE QUALITY AND PREPARATION
- o PATTERN ASSEMBLY
- o MAGNAFLUX INSPECTION
- o PART RECOGNITION
- o SAFETY AND SECURITY SYSTEMS
- o 3D REPLICATION (PARTS ON DEMAND)

VISION SYSTEMS

CURRENT TECHNOLOGY	APPLICATION AREA	SPECIFIC APPLICATION
2D BINARY VISION	INSPECTION, MEASUREMENT	SORTING, ASSEMBLY
2D GRAY SCALE VISION	DITTO	DITTO, PLUS BIN PICKING
3D (DOT-LINE SENSOR)	DEPTH GAGING AND CONTOUR	SCANNING
3D (PLANER-CCD CAMERA)	CONTOURING	MEASUREMENT, WELD TRACKING, INSPECTION
3D (STEREO)	MEASUREMENT	MAPPING, INSPECTION
3D (MULTIPLE PLANES)	SURFACE MEASUREMENT	COPYING, INSPECTION, MEASUREMENT

VISION SYSTEMS

CURRENT TECHNOLOGY	POTENTIAL APPLICATION	LIMITATIONS
2D BINARY VISION	----------	AMBIGUITY SURFACE REFLECTANCE
2D GRAY SCALE VISION	----------	AMBIGUITY
3D (DOT-LINE SENSOR)	GRINDING, DRILLING, ETC.	DAYLIGHT, SHADOWING
3D (PLANER-CCD CAMERA)	GRINDING, DRILLING, PARTS MFG., MOBILE ROBOT	DAYLIGHT, SHADOWING
3D (STEREO)	----------	COMPUTATIONALLY INTENSIVE
3D (MULTIPLE PLANES)	AS ABOVE; MOBILE ROBOT	DAYLIGHT, SHADOWING

VISION SYSTEMS

CURRENT RESEARCH

- COLLISION AVOIDANCE
- GEOMETRIC REASONING
- PLANNING AND STRATEGIES
- RECOGNITION
- APPLICATIONS OF 3D VISION
  - INSPECTION/MEASUREMENT
  - WIRE HARNESSING
  - GRINDING
  - WELDING
  - MATERIAL HANDLING
  - ASSEMBLY/DISASSEMBLY
  - DRILLING/ROUTING

HANDS AND END EFFECTORS

PROCESS APPLICATIONS

1. MATERIALS HANDLING
2. MACHINE LOAD
3. WELDING
4. PAINTING
5. STRIPPING/DEPOSITING
6. CLEANING/BLASTING
7. METAL SPRAY
8. SHOT PEENING
9. GRINDING
10. CUTTING
11. INSPECTION
12. DISASSEMBLY
13. ASSEMBLY
14. DEBURRING
15. MASKING

MANTECH NEEDS

1. ASSEMBLY/DISASSEMBLY (COMPONENTS)
2. WIRE HARNESS ASSEMBLY
3. INSPECTION/GAGING
4. MARKING/ENGRAVING (LASER/OTHER)
5. LASER WELDING
6. MATERIAL APPLICATION

R&D NEEDS

1. ASSEMBLY/DISASSEMBLY (LARGE AND SMALL ITEMS)
2. WIRE HARNESS ASSEMBLY
3. AUGMENTED END EFFECTOR STRUCTURES
   - o VISION AUGMENTED
   - o TACTILE AUGMENTATION
   - o ADAPTIVE MECHANISMS
   - o LASER INTEGRATION
4. UNIVERSAL AND FLEXIBLE STRUCTURES
5. MULTIHAND STRUCTURES (AND INTEGRATED CONTROL SYSTEMS)

SENSOR SYSTEMS

PROCESS APPLICATIONS

- AUTOMATED NDI
- WELDING
  - SEAM TRACKING
  - WELD QUALITY
- ASSEMBLY/DISASSEMBLY
  - CLOSE TOLERANCE PARTS
  - INCIPIENT DAMAGE
  - INSPECTION AND REPAIR
- BIN PICKING AND SORTING
- PACKAGING
  - SELECTING METHOD, ORIENTATION, ETC.
- RIVETING/DERIVETING
  - MATERIAL
  - TYPE
- PAINTING
  - SURFACE TRACKING
  - SURFACE FEATURES
- NON-CONTACT 3D GAGING
- GRINDING AND POLISHING
- SOLDERING/DESOLDERING
  - PRESENCE OF SOLDER
  - FLUID DISPENSE VERIFICATION
- SECURITY SYSTEM - INTRUSION
- PWB ASSEMBLY
- CHEMICAL/PHYSICAL MIXING
- FUEL LEAK DETECTION

SENSOR SYSTEMS

MANTECH NEEDS

- o GENERIC SENSOR INTERFACES
- o NDI SENSORS FOR ROBOTS (ALL TYPES)
- o INTEGRITY SENSOR
- o TACTILE MATERIAL HANDLING SENSORS
- o REAL TIME WELD PARAMETRIC SENSORS
- o COMPOSITE MATERIAL COMPOSITION SENSOR
- o FUEL LEAK DETECTION FOR ROBOT APPLICATION

R&D NEEDS

- o HOLOGRAPHIC PARTS ID
- o FAST MATERIAL COMPOSITION ANALYSIS
- o INTEGRATED FLOW DETECTION AND REPAIR CAPABILITY
- o TASK-SPECIFIC SENSORS
- o INTEGRATED SENSOR SYSTEMS
- o ENABLING SENSOR DEVELOPMENTS

TRANSPORTABILITY AND MOBILITY

APPLICATIONS

- PAINTING
- WELDING
- SANDING/BLASTING
- MULTI-STATION SYSTEMS
- AMMUNITION HANDLING
- NUCLEAR HARDENING
- FIREFIGHTING
- ORDNANCE LOADING/UNLOADING
- FLEXIBLE MACHINING/MFG SYSTEMS
- CHEMICAL CLEANUP/CLEANING
- LARGE STRUCTURE MECHANICS
  - INSPECTION/TEST
  - PROCESS-WELDING, CUTTING, COATING, ETC.
- STRIPPING
- STORAGE AND RETRIEVAL
- FUELING/DEFUELING
- PLATING
- AIRCRAFT TOWING
- ELECTRONICS TESTING
- AIRCRAFT RIVETING/DERIVETING
- ORDNANCE DISPOSAL
- MOBILE SCAFFOLDING
- EXPLOSIVES MIXING
- CUTTING
- PATCHING AND REPAIR
- TOOL STORAGE/RETRIEVAL
- METAL SPRAYING/COATINGS

TRANSPORTABILITY AND MOBILITY

APPLICATIONS

- o PAINTING
- o WELDING
- o SANDING/BLASTING
- o MULTI-STATION SYSTEMS
- o AMMUNITION HANDLING
- o NUCLEAR HARDENING
- o FIREFIGHTING
- o ORDNANCE LOADING/UNLOADING
- o FLEXIBLE MACHINING/MFG SYSTEMS
- o CHEMICAL CLEANUP/CLEANING
- o LARGE STRUCTURE MECHANICS
  - o INSPECTION/TEST
  - o PROCESS-WELDING, CUTTING, COATING, ETC.
- o STRIPPING
- o STORAGE AND RETRIEVAL
- o FUELING/DEFUELING
- o PLATING
- o AIRCRAFT TOWING
- o ELECTRONICS TESTING
- o AIRCRAFT RIVETING/DERIVETING
- o ORDNANCE DISPOSAL
- o MOBILE SCAFFOLDING
- o EXPLOSIVES MIXING
- o CUTTING
- o PATCHING AND REPAIR
- o TOOL STORAGE/RETRIEVAL
- o METAL SPRAYING/COATINGS

INTRODUCTION

The extraordinary pace of recent technology development and application in factory automation and robotics coupled with the pressing need to modernize and increase the productivity and performance of scarce resources in the organic industrial base of the Army, Navy, and Air Force led to the tri-service decision to conduct a DOD Depot Robotics Application Workshop Oct 4-7 1983, in Sacramento, California. This landmark event for the first time brought together - in a structured way-leading edge robotics practitioners possessing a proven track record of implementation successes in the private sector, and the Air Force, Army, and Navy depot personnel responsible for conception, planning, management, execution, and utilization of modernization and productivity enhancement projects.

The workshop represented a rare and never before achieved synergism of the entire in-house industrial base of the three services, focused on a single technology and its applications. The compelling scope, breadth, and depth of DOD organic industrial operations as revealed in the workshop presentations brought home to attendees a realization of the exceptional value and importance of this extraordinary industrial complex to the Department of Defense and the United States.

The workshop surfaced great interest and intent in Robotics and the instruments of automation because the current DOD depot, arsenal, shipyard, ordnance and supply, and aeronautical rework activity annual investment in direct touch labor is very large. The DOD Aeronautical Depots alone expended more than 82M direct manhours in FY 83 in in-house remanufacturing, maintenance, and repair of aeronautical weapon systems and associated products. Approximately one-half of this substantial investment was in the production of components, where direct touch labor is the dominant cost factor. Existing weapon systems acquisition plans and programs, if carried to reasonable percentage of execution, promise to further stress the current DOD work force and physical plant and its capacity to efficiently produce products in support of service operations. The application of labor-saving technology is thus seen as a mandatory adjunct to the continuing effort by service activities to improve performance and the utilization of limited plant, equipment, capital, and human resources.

Modernization of these precious and invaluable resources should hold an uncompromised priority in any balanced defense program. Too often, however, investments in the DOD in-house industrial complex are delayed or rejected in favor of investment in the weapons and products the DOD activities are chartered to support. The result is inevitably a continuing and burdensome growth in the life cycle cost of ownership of DOD assets, a corresponding decrease in the portion of the DOD dollar available for new weapon and military asset acquisition, and an ongoing deterioration in the overall vitality and efficiency of the service-organic industrial complex. Perhaps a Robotics and Automation pool of dedicated fiscal resources held, administered, and replenished at the DOD level and meritoriously competed on a project basis by the three services is what is required to insure that erosion of investment intent does not occur.

In any event, it is certain that aggressive and persistant long-term direction and action by the Congress and the Department of Defense are necessary to insure that the three services plan and vigorously implement a modernization program with short, mid, and long term components of capital investment, technology transfer (mantech) and manufacturing research. The investment menu surfaced by the DOD Robotics

Applications Workshop represents an exceptional opportunity to appropriately dedicate fiscal resources to achieve specific, meaningful productivity and performance enhancement of the DOD in-house industrial base.

The workshop was structured as follows: (1) Private sector experts selected by The Robot Institute of America (RIA) conducted state-of-the-art Briefs on Robotics and Automation systems; (2) representatives of all the DOD industrial activities of the three services save one (Norfolk Naval Shipyard did not attend) presented briefs on their industrial processes and operations, process economics, current robotics projects, and plans for the future; and (3) brainstorming roundtables led by experts from private industry and staffed by DOD attendees took advantage of the enhancement and synergism effected by (1) and (2) to discuss and generate menus of needs and investment opportunities in current applications, technology transfer, and research for ten robotics-related technical areas. A multi-media evening program was included to facilitate total immersion in the technology of interest.

The benefits derived from the workshop were many. They included: (1) the opportunity for DOD industrial depot personnel to receive information on successful robotics techniques and applications now occurring in the private sector and at other DOD depots; (2) the opportunity for depot personnel to receive state-of-the-art briefs on current technology and a timetable on new developments in the robotics field; (3) the chance for participants to compare production problems, plans, and needs with other depot professionals in a structured exchange and problem solving environment; (4) a rare chance for attendees to influence the thrust and direction of a proposed manufacturing technology and applied research initiative - to be undertaken within the existing programmatic framework of the three services - whose purpose is to directly address both generic needs and specific application opportunities for robotics and allied automation technology in the service industrial depots; and (5) a unique chance for both depot and selected private sector invitees to be exposed to the process and application areas of our valuable in-house industrial complex, to the end of providing both the understanding of these capabilities and the stimulation to research, develop, and apply nuances of robotics and automation technology to industrial operations heretofore not considered for such an application. The workshop proved to be classically effective in terms of its direct and immediate benefit to participating DOD activities in their equipment, technology, and modernization planning and acquisition efforts. Further, it is believed that the participants' enhanced knowledge and understanding of a fountainhead automation technology will yield enduring long-term benefit to the production posture of the participating service organizations.

The workshop brought a mix of private sector principals from academia, the user community, original equipment manufacturers, turn-key systems houses, and consultant organizations to interact with DOD engineers and managers responsible for technical implementation and resource allocation decisions. The result was both a phenomenal growth in knowledge and understanding by all of both robotics technology and the activities of the DOD industrial base. From these interactions it became apparent to many attendees that many of the issues and developments of interest to the DOD industrial activities possess the potential for applicability in the marketplace. Thus, investments made in project opportunities surfaced by the workshop could ultimately provide significant leverage on the competitive posture of the U.S. robotics industry worldwide. The existence of this beneficial multiplier would seem to provide further impetus for prompt and sustained action by the DOD to pursue the investment menu in robotics research and technology developed by the workshop.

DOD ROBOTICS WORKSHOP CONCEPT

- Initiated by MTAG CAD/CAM and metals subcommittees
- All segments $10B/yr organic base
- Industrial process emphasis
- Service-private sector information exchange
- RIA-managed industry participation
- Goal: Investment opportunity identification
  - Current applications
  - MANTECH
  - R&D
- Goal: Enhanced tri-service industrial base technology emphasis
- Goal: DOD sponsored tri-service depot focused technology investment program

305.1905.6861

WORKSHOP STRUCTURE

- Robotics briefs (RIA)
  - State of the art
  - Current installations/experience
  - The future: projections
- The DOD organic industrial base
  - Basic processes/technologies
  - Process economics
  - Current robotics/automation installations
  - Planned/future applications
- Roundtables
  - Ten related topics
  - Eight roundtables
  - Three sessions/topics
  - Led by private sector
  - Roundtable products
    - Process-technology matches (current)
    - MANTECH depot robotics needs
    - Depot robotics research needs

DOD ROBOTICS WORKSHOP

Multi-media Evening Program

Speaker	Affiliation	Topic	Date
Victor Scheinman	Automatix, Inc.	"A CAD Update"	4 Oct
R. Hohn	Cincinnati MILACRON	"Applied Robotics"	4 Oct
J. Atkinson	Cincinnati MILACRON	"Applied Robotics"	4 Oct
B. Whetsel	Cincinnati MILACRON	"Applied Robotics"	4 Oct
Vern Estes	General Electric	"Robot Applications"	4 Oct
Tom Hildick	Dept of Energy	"Robot Applications"	4 Oct
Roger Nagel	Lehigh University	"New Manufacturing Systems"	5 Oct
Ken L[illegible]	Portsmouth Navy Yard	"Production Line Concept for Overhauling Submarines"	5 Oct
John [illegible]	[illegible] Robotics	"Robotics"	5 Oct
Dean Anderson	Ford Motor Company	"Robotics Applications"	5 Oct

DOD ROBOTICS APPLICATION WORKSHOP

Presentors and Participant Guide

Presentors:

1. All private sector presentations will be free of marketing or sales effort; the goal is maximum transfer of technical information to participants.
2. All presentations are to be developed utilizing either vu-graphs or 35/42mm slides.
3. Hard copies of all presentation material must be provided to the workshop coordinator prior to September 1 so it can be used in assembling a workshop handbook.
4. All presentations are to be as detailed as possible in the time allotted. Depot presentations on process detail should include: (a) process name; (b) a chart of a typical process sequence; (c) touch labor operations should be noted for emphasis; and (d) the economic significance of the process should be noted (i.e., number of units, labor hours per current unit of output, most costly operations in the sequence, hazardous or unpleasant environmental conditions, etc.).
5. Summary and matrix charts are to be used whenever possible to compress information.

Participants:

1. You must prepare for this workshop. If you are from a depot, you must be prepared to discuss the following: (a) the principal industrial processes at your activity; (b) the basic process sequences; (c) the economic significance (ranking) of same; (d) the business volume for each process now and as projected for the mid-term (3 years) horizon; (e) the extent of touch labor in the current process; (f) modernization plans (if any) for your activity, and their potential effect on the principal industrial process sequences at your activity; (g) current and planned robotics projects at your activity, including both technical and administrative project detail; and (h) the projected future process and technology needs of your depot, based on the best available workload projections.

Presentation Subject Overview

The objective in a data matrix prepared for presentation at the DoD Depot Robotics Workshop is to provide the maximum amount of procedural, economic, and technical information possible in as compressed and summary a format as possible. The basic subjects to be presented by the DoD activities are:

1. Industrial Processes/Sequences
2. White Collar (staff) Processes
3. Current Robotics Projects
4. Planned Robotics Projects
5. Potential Robotics Projects

The basic subjects to be presented by the private sector invitees are:

A. Robotics Overview
   1. What are robot systems, parameters, specifications, etc.
   2. Current applications
   3. What robots can do
   4. Limitations/caveats and "experiences."
   5. State-of-the-art: What is new and what is coming soon.
   6. Current research and development efforts
   7. A view of the future: Total systems integration.

B. Robotics Project Mini-Tutorial
   1. Robotics application assessment
   2. Robot cost/pay back analysis
   3. Robot investment decision analysis
   4. Robot implementation
      a. System installation/checkout
      b. System integration
      c. etc.
   5. Robot life cycle support
      a. Maintenance (Hardware)
      b. Training/work force program
      c. Software support/maintenance
      d. Technical data
      e. etc.

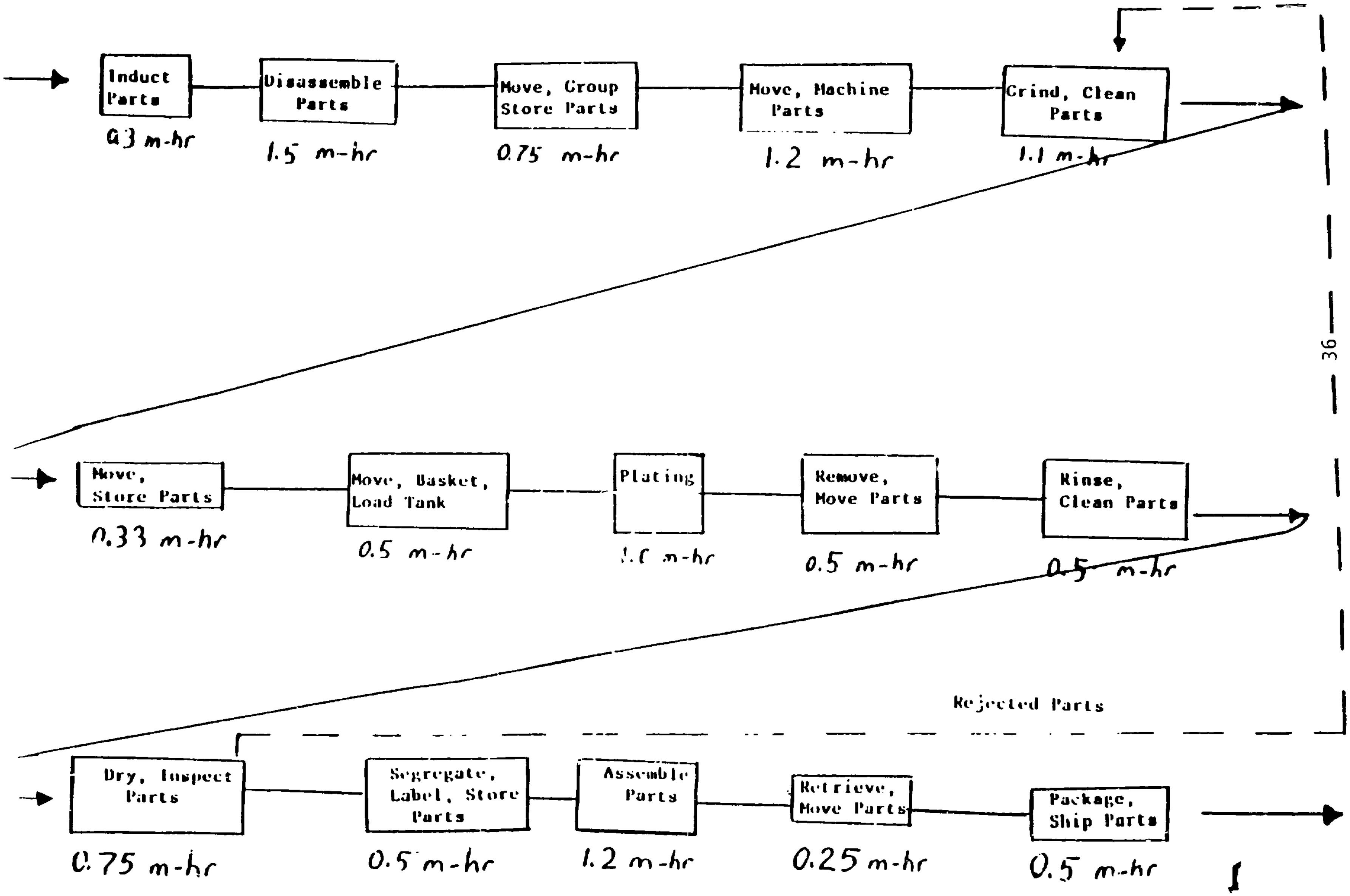
SAMPLE PROCESS INFORMATION MATRIX FORMAT

Process	Touch Labor Hrs/yr (K)	Total Cost/yr (K)	Hazardous/ Unpleasant work env.	Labor Skill Required	Job Training	Key OPN's Common to other Processes
Welding	50	1,500	yes	high	2 yr appr.	yes
Metal Cutting/ Forming	42	1,260	yes	Mod-high	4 yr appr.	yes
Electrical Test	190	5,700	no	high	4 yr appr.	yes
Dissassembly	960	28,800	no	low	1 yr trng.	yes
Assembly	1,020	30,600	no	high	4 yr appr.	yes
Material Handling	955	28,650	no	low	3-6 month OJT	yes
Material vement/ ting	292	8,760	no	low	3 month OJT	yes
Packaging/ Pres	112	3,360	no	mod	1 yr trng. and OJT	yes
Material Storage/ Retrieval	60	1,800	no	low	6 month trng. and OJT	no
Parts Cleaning	27	810	yes	low	3 month OJT	no
Deburring & Finishing	17	510	yes	mod	2-4 yr appr.	no
Plating	14	420	yes	high	4 yr appr. & OJT	no
Heat Treating	11.5	345	yes	mod-high	4 yr appr. & OJT	no
AAAABXY	ZZZZZ	NNNN	yes	high	4 yr appr.	yes
Totals						

Other columnar data titles of interest might include the following: "Boring/ etitive", "Precision Required", "Product Design Complexity", Product Fragility", terial Cost", "Scrap Rate", "Part Size", "Part Weight", "Support Equipment Maint. Cost", "Skilled Labor Availability", "Unit Product Volume/yr", "Process Environment", etc.

SAMPLE DETAILED PROCESS ANALYSIS

Process: Plating



SAMPLE SUMMARY ANALYSIS OF .REVIOUS SEQUENCE

ıduct, Disassemble Move Parts	Machine, Grind Parts	Load, Plate Parts	Clean, Inspect Parts	Assemble Parts	Package, Ship Parts
2.55 m-hrs	2.63 m-hrs	2.00 m-hrs	1.75 m-hrs	1.2 m-hrs	0.75 m-hrs

37

ſAILED PROCESS SEQUENCE:

tal man-hours: 10.88/load
tal labor hours/yr.: 14,000
tal labor cost/yr.: $420,000
tal parts loads /yr: 1,287
erage loads /day: 4.9
st/load (@$30/m-hr): $326.40
rts /load: 100
jection rate: 10%
g. Labor cost/part: $3.60

Disassembly, handling: 80¢
Machining, grinding, handling: 80¢
Plating, handling: 70¢
Cleaning, inspecting, handling: 60¢
Assembly: 40¢
Packaging and shipping: 30¢

SAMPLE ROBOTICS PROJECT SUMMARY INFORMATION MATRIX

Activity: Aircraft Depot XYZ

Project	Date	Project Mgr.	Cost	Process Automated	ECD	Misc.
Automated Tail Bender	FY 82	Jay Endeffector	240	Straighten F&U Tails	6/84	Utilizes Laser Holograph Vision System
Robotic Tire Tester	FY 83	Lionel Gripper	330	Auto Test and handle Guy Rubber Tires	9/85	Multi-arm Robot Bounce-Tests Tires
Small Parts Fetch	FY 84	Fred Tactile	150	Walking Robot Inter-Facing with Small Parts Bin-dump	1/85	Aircraft Small Parts on Prod. Floor. Voice Programmable
Apprentice Chute Trainer	FY 81	Geronimo R2D2	230	Robot Packs and Tests Parachutes	Comp.	Chute Redesign to accommodate robot robot pack

The object here is to provide a quick compressed summary of robotics projects in execution, completed, and planned. This is only a sample summary. Other columnar headings which might be relevant include: "Unique Features", "Special Problems", "Payback Period", "Type of Installation" (i.e. stand alone, system integration, etc), "Software Language", etc. , etc.

ROBOTICS APPLICATION WORKSHOP STAFF

SERVICE CHAIRS:	
ARMY:	ROBERT HELLEM, IBEA,DRXIB-MM
AIRFORCE:	LAZLO HARY, HQ AFLC/MAXT
NAVY:	FORREST GALE, DSMC (HQ NAVMAT)
DOD ROBOTICS APPLICATION WORKSHOP CHAIRMAN:	WILLIAM WALDEN, SM-ALC/MAW
PRESIDENT OF SOLE:	SUE O'NEIL, SM-ALC/MMI
FINANCE MONITOR OF SOLE:	MARILYN MILLER, SM-ALC/MMK
FINANCE MONITOR OF MA:	PAT DWYER, SM-ALC/MAW
ACCOMMODATIONS PLANNER:	KAREN HARPER, SM-ALC/MAW
AUDIO-VISUAL AND PUBLICATIONS:	GEORGE ANDERSON, SM-ALC/MAA
	MIKE CHANDLER, SM-ALC/MAA
	BETTY HOYT, SM-ALC/MAA
	DON HAMMERSTEN, SM-ALC/MAA
	KEITH DANKERTSEN, SM-ALC/MAW
PROTOCOL:	SHEILA MCFALL, SM-ALC/MAA
	MARSHA WALLACE, SM-ALC/MAA
ADMINISTRATIVE ASSISTANT:	EDNITA R. OVERSTREET, SM-ALC/MAW

AGENDA

DOD ROBOTICS APPLICATION WORKSHOP

Sierra Inn, Sacramento, CA

Redwood Ballroom

MONDAY, 3 Oct 83

1600 - 2000	Registration	Sierra Inn Pecan Room

TUESDAY, 4 Oct 83

0700 - 0900	Registration	Sierra Inn, Room 151
0800 - 0810	Welcome	Brig Gen T.A. Hammond Vice Commander, Sacramento Air Logistics Center
0810 - 0815	Workshop Administrative Details	W. Walden, SM-ALC
0815 - 0825	Introduction	J. Sullivan, IBEA
	OVERVIEW OF THE STATE-OF-THE-ART IN ROBOTICS AND APPLICATION ASSESSMENT SESSION	
	Moderator: Dr K. McKee, Manufacturing Productivity Center	
0830 - 0850	Robot implementations and associated benefits	V. Estes, General Electric Co.
0850 - 0910	Current robot applications and direction of research	D. Anderson, Ford Motor Co.
0910 - 0930	Robot system experiences, successes and failures	R.M. Hills, General Dynamics Corp.
0930 - 0950	Robot systems performance and capabilities	R. Hinson, Robot Systems Inc.
0950 - 1010	Overall analysis of current robot systems	R. Hohn, Cincinnati Milacron
1010 - 1025	Break	
1025 - 1045	State-of-the-art in applied research and its direction	Dr R. Nagel, Lehigh University

1045 - 1105	Robot technology and human factors	J.E. Taylor, HumRRO
1105 - 1125	General issues for manufacturing policy - balance for R&D	Dr D. Tesar, University of Florida
1125 - 1145	Current successful robot applications	G. VanderBrug, Automatix Inc.
1145 - 1205	Robot welding systems	J. Fouse, Vought Corp.
1205 - 1225	The future - What does the next decade hold?	M. Knasel Science Applications Inc.
1225 - 1345	Lunch	
	DEPOT PROCESS REVIEW SESSION	
	Moderator: F. Gale, Defense Systems Management College	
1345 - 1400	Air Force Aircraft Repair	G. Langenbeck, SM-ALC/MAB
1400 - 1415	Air Force Engine Repair	M. LeBlanc, OC-ALC/MAE
1415 - 1430	Air Force Electronics Repair	W. Ramsey, WR-ALC/MAI
1430 - 1445	Air Force Landing Gear Repair	Lt Col Hruskocy, OO-ALC/MAN
1445 - 1455	Navy Depot processes	NARF Alameda
1455 - 1505	Navy Depot processes	NARF Cherry Point
1505 - 1515	Navy Depot processes	NARF Jacksonville
1515 - 1525	Navy Depot processes	NARF Norfolk
1525 - 1535	Navy Depot processes	NARF North Island
1535 - 1545	Navy Depot processes	NARF Pensacola
1545 - 1600	Break	
1600 - 1700	Navy Shipyard processes	NSY Charleston
	Navy Shipyard processes	NSY Long Beach
	Navy Shipyard processes	NSY Mare Island
	Navy Shipyard processes	NSY Norfolk
	Navy Shipyard processes	NSY Pearl Harbor
	Navy Shipyard processes	NSY Philadelphia
	Navy Shipyard processes	NSY Portsmouth
	Navy Shipyard processes	NSY Puget Sound

1700 - 1720	Question/Answer and Discussion	
1720	Adjourn	
1720 - 1735	Roundtable Leaders Meeting	Location to be announced.
1830 - 2030	No Host Social Hour	Redwood A Room
2030 - 2200	Evening program, to be announced.	Pecan and Sequoia Rooms

WEDNESDAY, 5 Oct 83

	DEPOT PROCESS REVIEW SESSION - CONTINUED	
	Moderator: J. Sullivan, IBEA	
0800 - 0820	Exploration & analysis of process sequences	J. Nitterhouse, Letterkenny Army Depot
0820 - 0830	Current operation and economics of welding, plating, painting and van assembly	E. Helalian, Sacramento Army Depot
0830 - 0845	Combat vehicle track and suspension overhaul and conversion operations	W. Oosterveen, Red River Army Depot
0845 - 0900	Overhaul of communications - ele[illegible]ronic shelters	F. Estock, Tobyhanna Army Depot
0900 0915	Use of robotics in material handling of hazardous materials	F. Eldriege, Tooele Army Depot
0915 - 1000	Navy Weapon Stations	NWS Charleston
	Ordnance Depots	NWS Concord
	"	NWSC Crane
	"	NWS Earle
	"	NOS Indian Head
	"	NUWES Keyport
	"	NOS Louisville
	"	NWS Seal Beach
	"	NWS Yorktown
1000 - 1015	Break	
	CURRENT DEF[illegible]OBOTICS PROJECTS SESSION	
	Moderator: L. Hary, AFLC/MAXT	
1015 - 1025	Air Force, Blade Repair	M. LeBlanc, OC-ALC/MAE

1025 - 1035	Air Force, Plasma Spray at SA-ALC	S. Lee, AFWAL/MLTM
1035 - 1045	Air Force, Honeycomb Shaping at SM-ALC	G. Betz, Robotic Vision
1045 - 1055	Air Force, Robotic Painting	Col R. Grabler, OO-ALC/MAW
1055 - 1120	Navy Robotics projects	NARFS
1120 - 1130	Navy Robotics projects	YARDS
1130 - 1135	Navy Robotics projects	NWS/NOS
1135 - 1145	Neo-robotic application development	J. Nitterhouse, Letterkenny Army Depot
1145 - 1155	Feasibility and economic considerations of robotic applications at welding shop	E. Helalian, Sacramento Army Depot
1155 - 1205	Robotic applications to combat vehicle track and suspension overhaul and conversion operations	W. Oosterveen, Red River Army Depot
1205 - 1215	Application of robotics to shelter refinishing	S. O'Malley, Tobyhanna Army Depot
1215 - 1325	Lunch	
	POTENTIAL DEPOT APPLICATIONS AND PLANS FOR THE FUTURE	
	Moderator: J. Sullivan, IBEA	
1335 - 1345	DLA Depot Automation	Col T. Kirkham, Defense Logistics Agency
1345 - 1355	Laser Paint Removal	T. Mallets, AFLC/MAXT
1355 - 1405	Air Force Materials Laboratory Plans/Projects	S. Lee, AFWAL/MLTM
1405 - 1415	AIM Industry/Depot Survey	F. Brooks, AFSC/PMI
1415 - 1425	OO-ALC plans	Col R. Grabler, OO-ALC/MAW
1425 - 1435	SA-ALC plans	Lt Col J. Ferry, SA-ALC/MAW

1435 - 1445	Robotics in NDI, SM-ALC	D. Froom, SM-ALC/MAN
1445 - 1500	Navy plans	NARFS
1500 - 1515	Navy plans	Shipyards
1515 - 1530	Break	
1530 - 1545	Navy plans	NWS/NOS
1545 - 1600	Navy plans	NCS San Diego/ NAVSUPHQ PWC/NAVFACHQ
1600 - 1610	Robotic systems for camouflage painting, welding, laser engraving and the integration of state-of-the-art end effectors to planned systems.	J. Nitterhouse, Letterkenny Army Depot
1610 - 1625	Engineering and economic considerations of potential robotic applications	E. Helalian, Sacramento Army Depot
1625 - 1635	Robotic camouflage painting of the M113 vehicle family	W. Oosterveen, Red River Army Depot
1635 - 1700	Field applications for robotic material handling systems	C. Shoemaker, Human Engineering Laboratory, and F. Eldriege, Tooele Army Depot
1700 - 1730	Questions & Answers	
1730	Adjourn	
2030 - 2200	Evening program, to be announced.	Pecan and Sequoia Rooms

THURDAY, 6 Oct 83

ROUNDTABLE SESSIONS

Locations to be posted.

Moderator: F. Gale, Defense Systems Management College

0800 - 0910	Simultaneous Roundtables - Session 1 (see attachment for topics and leaders)	Government & Industry
0910 - 1020	Simultaneous Roundtables - Session 2 (see attachment for topics and leaders)	Government & Industry
1020 - 1035	Break	
1035 - 1145	Simultaneous Roundtables - Session 3 (see attachment for topics and leaders)	Government & Industry
1145 - 1305	Lunch	
1305 - 1515	Roundtable Summary Presentations (10 each, 13 min presentations)	Chairpersons
1515 - 1530	Break	
1530 - 1700	Open Discussion & Wrap-up Summary	J. Sullivan, IBEA
1700	Adjourn	

FRIDAY, 7 Oct 83

0830 - 1130	Tour of SM-ALC Production Operations (Optional)	
or		
0800 - 1600	Robotic Conference at California State University, (Optional -- See Flyer: "Towards Intelligent Robots.")	

NOTE: Registration/reception desk will be open on Monday, 3 October from 1600 - 2000 in Pecan Room, Sierra Inn. The desk will be open in Room 151 from 0700 - 0900 on Tuesday, 4 October to accommodate late arrivals.

DOD ROBOTICS APPLICATION WORKSHOP

ROUNDTABLE SESSIONS

Moderator: F. Gale,
Defense Systems Management College

	Roundtable Topics	Leaders
1.	Potential Applications	V.E. Estes, General Electric Co. D. Anderson (co-leader), Ford Motor Co.
2.	Robot Installation/Design Concepts	R. Hinson, Robot Systems Inc.
3.	Robot Safety/Security	R. Hohn, Cincinnati Milacron
4.	Robot Language Concepts/Development	Dr R. Nagel, Lehigh University
5.	Robot Mechanical Systems/Precision Operations	Dr D. Tesar, University of Florida
6.	Robot Vision	G. Betz, Robotic Vision Systems Inc.
7.	Robot Control and Integrated Systems	J. Evans, Nova Robotics Inc.
8.	Robot Hands and End Effectors	R. Hills, General Dynamics Corp.
9.	Topic to be Announced	G. VanderBrug, Automatix Inc.
10.	Robot Transportability/Mobility	M. Knasel, Science Applications Inc.

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PROGRAM

INTRODUCTION

PRESENTED BY

JAMES H. SULLIVAN
CHAIRMAN
MANUFACTURING TECHNOLOGY ADVISORY GROUP
CAD/CAM SUBCOMMITTEE

GOOD MORNING; THAT IS, GOOD MORNING TO THOSE OF YOU FROM THE WEST COAST.

I UNDERSTAND WE HAVE PEOPLE PRESENT FROM ALL AROUND THE GLOBE. I SUPPOSE THE PERSON FROM HAWAII IS STILL ASLEEP. YOU FROM THE EAST COAST ARE PROBABLY READY FOR LUNCH, AND THE INDIVIDUALS FROM GERMANY ARE READY FOR A BEER ... I MEAN DINNER.

WELL, I AM FROM THE MID-WEST SO THE JET LAG WAS EASY TO ADAPT TO. HOWEVER, BEING FROM THE MID-WEST, IT IS ALWAYS HARD TO ADAPT TO FALL & WINTER SO WOULD THE PERSON FROM HAWAII PLEASE KIDNAP ME WHEN YOU RETURN HOME.

ON BEHALF OF THE DEPARTMENT OF DEFENSE MANUFACTURING TECHNOLOGY ADVISORY GROUP, I WOULD ALSO LIKE TO WELCOME YOU TO THE DOD ROBOTICS APPLICATION WORKSHOP.

THE AGENDA THIS WEEK IS EXTREMELY TIGHT, AND BEFORE WE REALIZE IT, I WILL BE STANDING HERE AGAIN CLOSING THE AGENDA AND THANKING YOU FOR ATTENDING.

ACTUALLY, I HOPE WHEN THE WORKSHOP ENDS ON THURSDAY INSTEAD OF ME THANKING YOU FOR ATTENDING AND <u>PARTICIPATING</u>, IT WILL BE YOU THANKING THE WORKSHOP STEERING COMMITTEE FOR EXTENDING THE INVITATION AND PROVIDING THIS OPPORTUNITY.

IF YOU CAN PICTURE THE WORKSHOP TITLE FOR A MOMENT, "DOD ROBOTICS APPLICATION WHORKSHOP" LET'S BRIEFLY ANALYZE EACH WORD AND CHOOSE THE KEY UNDERLYING THIS EVENT:

DOD .... THERE IS NO DOUBT THAT DOD IS SIGNIFICANT SINCE THE THREE MILITARY SERVICES ARE FINANCING US THIS WEEK. BUT WE COULD HAVE USED THE TITLE: ROBOTICS APPLICATION WORKSHOP.

ROBOTICS ..... THIS IS IMPORTANT; HOWEVER, WE COULD REPLACE ROBOTICS WITH PROGRAMMABLE AUTOMATION, OR MAYBE STAR WARS ACTION FIGURES..

APPLICATION ... NOW WE ARE GETTING CLOSE; IN ORDER FOR TECHNOLOGY TO HAVE A SIGNIFICANT IMPACT, IT MUST BE APPLIED.

WORKSHOP ...... WORKSHOP ONLY DENOTES ONE THING, "PARTICIPATION" AND HERE IS THE KEY TO INSURING THAT THIS EVENT IS SUCCESSFUL. IT IS THE ONE INGREDIENT THAT THE STEERING COMMITTEE ASKS YOU TO PROVIDE.

LET ME RELATE MY PLEA TO A CONVERSATION I HAD WITH MY 4-YEAR OLD SON LAST MONTH. AS I WAS PUTTING HIM TO BED ONE EVENING, HE TOLD ME TO GET HIM A GLASS OF WATER. I THEN PROCEEDED TO EXPLAIN TO HIM THAT LITTLE BOYS ASK THEIR DADDIES FOR THINGS AND THAT DADDIES TELL LITTLE BOYS WHAT TO DO. FEELING THAT I HANDLED THE SITUATION SATISFACTORILY, I GAVE HIM A DRINK AND FIRMLY SAID, "NOW I WANT YOU TO GO TO SLEEP." AFTER WHICH HE RESPONDED, "DADDY, I AM NOT GOING TO SLEEP."

WELL, BEFORE LONG, HE WAS ASLEEP AND I ENCOURAGE YOU NOT TO WAIT TOO LONG TO ROLL UP YOUR SLEEVES AND GET INVOLVED .... FOR YOU WILL ONLY GET OUT OF THIS WORKSHOP WHAT YOU, AS A GROUP, CONTRIBUTE.

WHAT CAN YOU EXPECT OVER THE NEXT THREE DAYS?

FIRST - A TIGHT SCHEDULE. AND I MUST WARN YOU, ALL SESSION MODERATORS HAVE BEEN TOLD TO KEEP ON SCHEDULE.

SECOND - DO TO THE OVERWHELMING RESPONSE, YOU CAN EXPECT TO FEEL THAT THE PERSON SITTING NEXT TO YOU, BEHIND YOU, AND IN FRONT OF YOU HAS MORE ROOM THAN YOU DO! IT IS MY UNDERSTANDING THAT WE HAVE 180 PERSONS PRESENT.

& THIRD - YOU WILL HEAR ABOUT:

- SUCCESSFUL ROBOTIC TECHNIQUES AND CURRENT APPLICATIONS
- AN UPDATE ON THE STATE OF THE ART AND NEAR TERM DEVELOPMENTS
- RELATED PRODUCTION PROBLEMS (MISERY LOVES COMPANY .... RIGHT?)
- THE ENDLESS RED TAPE THAT MAKES THE SIMPLEST TASK DIFFICULT, AND
- THE PROCESS AND CAPABILITIES OF DOD IN-HOUSE FACILITIES.

THE AGENDA HAS BEEN LAID OUT IN A UNIQUE MANNER. FIRST, INDUSTRY EXPERTS WILL BRING THE AUDIENCE UP TO DATE ON THE STATE OF THE ART. SECOND, THE MILITARY INDUSTRIAL COMPLEX WILL BE DESCRIBED; AND THIRD, PANEL SESSIONS ARE SCHEDULED TO IDENTIFY APPLICABLE TECHNOLOGY SHORTFALLS. IT IS HERE THAT EACH OF YOU WILL HAVE THE OPPORTUNITY TO HELP IDENTIFY TECHNICAL SHORTFALLS THAT COULD BECOME THRUST AREAS FOR DOD MAN TECH PROGRAMS.

LET ME CAUTION YOU ABOUT THE WORKSHOP. DON'T LET HAPPEN TO YOU WHAT HAPPENED TO A FRIEND OF MINE. A FEW WEEKS AGO, WE WERE IN THE THE LOCKER ROOM AFTER A ROUND OF GOLF WHEN I COULDN'T HELP NOTICING THAT MY FRIEND WAS PUTTING ON A GARTER BELT AND STOCKINGS. REALLY NOT KNOWING WHAT TO SAY, I ASKED HIM WHEN HE STARTED WEARING THE EXTRA CLOTHES. HIS RESPONSE, "WHEN MY WIFE FOUND THEM IN THE GLOVE COMPARTMENT.'

WELL, DURING THE PANEL SESSIONS I HOPE YOU DEMONSTRATE MY FRIEND'S ABILITY TO THINK FAST, BUT UNLIKE MY FRIEND, DON'T LIMIT YOUR CONVERSATION TO WHAT YOU THINK THE OTHER PERSON WANTS TO HEAR ... INSTEAD, RELATE AND SHARE YOUR EXPERIENCES AND SITUATIONS AND STIMULATE INTERACTION.

I WOULD LIKE TO TAKE THIS OPPORTUNITY TO THANK BRIGADIER GENERAL HAMMOND AND HIS STAFF FOR HOSTING THIS WORKSHOP AND IN PARTICULAR MR. BILL WALDEN FOR THE MANY HOURS SPENT ON LOGISTICS SUPPORT.

I WOULD ALSO LIKE TO THANK THE ROBOT INSTITUTE OF AMERICA AND THEIR DESIGNATED REPRESENTATIVES FOR JOINING US. I ASSURE YOU THAT RIA DID AN OUTSTANDING JOB SELECTING THE INDIVIDUALS FROM INDUSTRY AND ACADEMIA WHO WILL PLAY A MAJOR ROLE THIS WEEK.

IN CLOSING, I WOULD LIKE TO INTRODUCE THE STEERING COMMITTEE. (I ASK YOU TO HOLD THE APPLAUSE). GENTLEMEN, IF YOU WOULD PLEASE STAND

MR. BOB HELLEM, US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY

MR. FORREST GALE, US NAVAL MATERIEL COMMAND (CURRENTLY ON SPECIAL ASSIGNMENT WITH THE DEFENSE SYSTEMS MANAGEMENT COLLEGE)

AND THE STEERING COMMITTEE CHAIRMAN,

MR. LASZLO HARY, HEADQUARTERS, US AIR FORCE LOGISTICS CENTER

THANK YOU, AND LET'S GET GOING.

--ABSTRACT--

OVERVIEW - K. MCKEE

ITT Research Institute

Dr. McKee discussed the Robot Institute of America role in robotics in America and the appropriateness of the timing for this workshop. He discussed the conduct of the workshop and the way in which the industry portion of the workshop would be conducted. He introduced each of the speakers and commented on their presentations, adding ad hoc supplemental remarks. He noted that the vision systems industry is one-half the size of the present robotics industry; an indication of how significant support systems are in the cost and function panorama. He averred that management support for robotics implementation is requisite to success, and that supplemental benefits like quality are difficult to quantify but nonetheless important. Major robotics applications include material and parts handling, and assembly. A challenge to the DOD was stated to be to design parts to be assembled and handled by robots. "Good planning for robotics applications is a must to insure success," said Dr. McKee. "Further, look for the cost of the robot to be equal to or less than 30-50% of the total cost of a robotics implementation," stated Dr. McKee. He noted that top down planning and the systems approach are necessary for the entire plant, to avoid suboptimization. Only when all the blocks are in place will the payoff be high; (ie) = interim benefits may not justify the indvidual investments. Finally, training in operation and maintenace is seen as a vital issue in the application of robotics.

ROBOTS - A Key Link In The Factory With A Future

Vern E. Estes

General Electric Company

You hear a lot about the "Factory-Of-The-Future" these days. We think you should be more concerned with your Factory-With-A-Future. Few people will have the opportunity to start a new factory from the ground up, but all of us have some relationship to an existing factory which we hope to give a future. Dependent on where your factory automation stands today, the Factory-With-A-Future concept could require revolutionary changes, but the most important part of this concept is the fact that it should be a never ending evolutionary update process.

Above all, don't wait for manufacturing technologies to settle down before buying. We are experiencing exciting times when you consider the manufacturing tools we have to work with. The advent of the shop hardened, compact, low priced computer is making things possible today that have been unheard of in the past.

I would love to discuss all of your Factory-With-A-Future opportunities, but I will limit myself to the subject of industrial robots, how, why, and where they fit.

There are two major areas. They are "Manufacturing and Test" and "Assembly and Test." We might also be able to clean offices in the future, but we will stick with the more practical applications of robots for this paper. Robots are today's #1 buzzword manufacturing technology, world wide. There are probably many reasons for this but the most important reason is that robots have both short term and long term benefits. Many of the other computer based manufacturing technologies being implemented today require rather extensive software develpment before any real benefits can be realized.

Before I get too deep into how robots fit into our factories, I should probably define a robot. I won't give you the full definition that the "Robot Institute of America" has come up with. The main thing to remember is that an industrial robot is reprogrammable and can perform multiples of tasks. Robots that are performing and welding operations today could be loading and unloading a machine tool a year from now. Herein lies one of the greatest assets of an automation system which utilizes robots. Much of the original cost of a robot system can be salvaged when design changes or new product lines come along. Dedicated automation can become totally obsolete under the same situation.

Because of the diversity of General Electric's manufacturing businesses, literally producing turbines to tooth brushes, we are presently the most diverse user of robots in the United States. We install robots in areas that are dirty, dangerous, or dull. One of our most popular applications is in die casting. Our experience is that a complete system can be installed for twice the cost of the robot itself. In most cases, the return on investment has been less than three years and in some cases, less than two years. The savings are mostly due to the controlled heat loss in the die which literally eliminates rework, reduces die maintenance, and last but not least, eliminates gloves which can cost as much as $6,000 per year.

Arc welding is also a very popular Factory-With-A Future robotic module. The main benefit in this process is increased arc time which may double or triple that of a manual operation. Additional benefits are being realized from reduced weld wire usage and improved quality of welds. The most recent breakthrough in arc welding is real time seam tracking utilizing lasers and solid state cameras to look at both the

weld seam and the weld puddle at the torch, through the arc. The system which was recently developed in our research labs, not only tracks the seam, but also analyses weld puddle width and controls this width by changing weld supply current, again in real time.

Spot welding has been performed in our company but not extensively. The automotive companies are the leaders in the use of robots in spot welding. This is a natural for robotics as spot weld guns are heavy and require heavy cables to bring the power to the gun. We also have robots in extrusion press applications, paint spraying, heavy parts handling and small part assembly.

Probably one of the least tapped applications for robots is programmable assembly. The programmable assembly robot to be successful, must be smart enough to sense bad parts and recover without human intervention. This capability is available today for the creative implementor. This category of robotic technology may be the most lucrative robot application and will extend the Factory-With-A-Future through assembly and test functions.

When we started our major robotics thrust in the General Electric Company in 1976, we had ten robots in place. Today we have well over 400 robots in place.

Typical by-products of these Factory-With-A-Future modules are quality improvements, increased productivity, and reduced manufacturing costs.

What does it take to get started in this technology? We can tell you that your managers have to be taught the benefits of the technology. This training has to be followed with education of the individual contributors who have to justify and implement. We developed training courses to satisfy these needs. It also helps if you can develop a team to assist operations in their first implementations. Success perpetuates new implementations. Failures can give major setbacks.

When it comes to applying robots you will come to the realization rather quickly that the toughest part of implementation will be the peripherals, not the robot. The problems can be in part orientation, hand design, layout, and even the psychological aspects of implementation.

Part orientation is getting easier with our recent breakthrough in the ability of the vision system, in a shop hardened form, to give the robot instructions for picking parts from randomly operated part bins. These systems will not only reduce cost of part orientation hardware per workstation, but will reduce setup from hardware changes to a terminal input of new part parameters.

We are truly in an exciting new industrial revolution driven by computers, servo mechanisms, and sensors. Our manufacturing operations will be monitored in real time correcting problems before they produce bad parts.

Robots are only one link in the Factory-With-A-Future. The next decade will be very exciting for those of us who can deal with the rapid changes that the computer will allow us to make in our manufacturing operations.

Jobs will be plentiful in these fields. Many of the jobs that our manufacturing people will be holding in the future don't even have names yet.

The major attributes of the implementor of these technologies will be common sense, enthusiasm, and willingness to work.

Some things never change.

CURRENT ROBOT APPLICATIONS AND DIRECTION OF RESEARCH

David Anderson

Robotics and Automation Application Consulting Center

Ford Motor Company

The Ford Motor Company has committed itself to be in the forefront of manufacturing technology including the applications of robotic technology. Currently Ford has over 1200 robots installed throughout its worldwide operations. These installations represent 65% welding operations, 25% parts handling, 8% tool handling, and 2% assembly operations. It is anticipated that the assembly operations will increase to 20 - 25% by 1990. Applications in the future include vision control, assembly, control systems, and gantry robots.

While these installations represent significant progress, Ford has recently taken steps to accelerate that progress with the formation of the Robotics and Automation Applications Consulting Center. The presentation included a discussion of the role of the Consulting Center and described several successful robot projects that are currently in place within Ford's worldwide operations, as well as those currently undergoing development within the Robot Center. It also discussed Ford's plans to train and familiarize its people with robot technology.

—ABSTRACT—

ROBOT SYSTEM EXPERIENCES, SUCCESSES, FAILURES

By: R. HILLS
General Dynamics Corporation

Mr. Hills discussed a number of successful implementations of robotics by General Dynamics in the F-16 program. General Dynamics set up a robotics lab in 1976. In 1977 work was started on drilling of the F-16 vertical stabilizer skin (composite) and a robotics cell was implemented in 1979. A robotics wing drilling program was initiated in 1981 as well as a robotics deburring operation. The analysis of a production operation (typical) at General Dynamics was described by Mr. Hills. Other application areas included in this presentation were sheet metal fabrication, tube fabrication, routing and end counter sinking, trimming, etc., primarily in aerospace structural assemblies for the F-16 aircraft. Mr. Hills described the process sequences automated, the implemented systems, and the benefits derived from the robotics applications. End effectors for assembly, sealant, and fastener application, etc., were discussed as was the advanced robotics control system to be utilized at G.E., a down-loaded factory floor control concept. Graphics simulation was stated to be a very important part of robotics system design and application.

—ABSTRACT—

ROBOT SYSTEM PERFORMANCE/CAPABILITIES

By: R. TROUTEAUD
Robotics System, Inc.

Mr. Trouteaud said that the robot can be as little as 10% of the total automated system cost, depending on the complexity of the application. There are now more than 100 different manufacturers of robots. Selection is now more difficult than before. Successful application of robotics requires education, commitment, support, involvement, imagination, good knowledge of the process, and—above all else—planning. The systems approach is most important. Collateral systems to the robot include end-of-arm tooling, sensors, memory capacities in satellite systems, etc. Cycle time, part weight, mobility, etc. are some of the system parameters that are important. Cost justification is an in-depth process of tradeoffs of quality, system performance, and of cost. Typical applications discussed by Mr. Trouteaud included welding cells, a number of machining operations, investment casting, core dipping (foundry), metal disc treating, inspection, material handling, spray painting, small and large part assembly, etc. In the systems approach, other key elements supporting a typical robot system discussed included the controller, power supply, spare parts storage, sub-component assembly system, special purpose machines, input and takeaway conveyors, inspection and gaging equipment, sensors for part presence, assembly and machining stations, tool compensation units, vibratory feeders, end-of-arm tooling inspection, work monitoring, end effector tool change systems, etc. "The robot is easy," said Mr. Trouteaud. "It is the support system that is complex and difficult to implement." Hand/end effector design is a high payoff area. One has to deal with "what is" in station design rather than what you would like it to be. Tradeoff features in conveyors, feeders, vision systems, guided vehicles, programmable work station controllers, etc. were discussed by the speaker, the goal being to maximize the entire system, not just the robot. Interactive graphics is a great aid in planning and insures that a simple project is indeed simple, and that the total systems approach is maintained.

—ABSTRACT—

ANALYSIS OF CURRENT ROBOT SYSTEMS

By: RICHARD E. HOHN
Cincinnati Milacron

Mr. Hohn discussed robot technology, applications, application selection guidelines, and things that promote the application of robots. He discussed the types of robots (pick and place, servo controlled point to point, continuous path, controlled path, etc.), how motion control is achieved, performance specifications (repeatability, accuracy, resolution), and applications (spot welding, palletizing, press loading/unloading, machine loading, drilling, routing, riveting, grinding, sealant application, gaging, laser machining including trimming, sheep shearing, etc.). Application selection considerations include: (1) pick easiest task; (2) identify all work being done; (3) identify cycle times; and (4) define the interfaces. Factors that promote the use of robotics include: (1) productivity potentials; (2) quality; (3) reduction of scrap; (4) safety and human factors in hazardous areas; (5) economic factors; and (6) flexibility.

Robotics Research

A State-of-the-Art Review and Current Directions

Roger N. Nagel
Professor, Director Institute for Robotics
Lehigh University

I will discuss the following five areas: Manipulators, Locomotion, End Effectors, Sensor Systems, and Control Structure and Programming

Manipulators - The design of robot arms has evolved in an ad hoc fashion. Todays robots are heavy, rigid, and use slide/rotary joints. Their conventional bearings have backlash, with repeatibility in .1 to .001 inch range, and no absolute accuracy. Many U.S. firms import arms. The mechanical design community has begun to work on robot geometry, actuation mechanisms, new linkage concepts, kinematic and dynamic models, new materials, and compliance. Current, near-term, and far-term manipulator designs are as follows:

CURRENT	NEAR-TERM	FAR-TERM
Rigid-heavy	Rigid-light	Light/flex
Stnd actuators backlash	Rare earthy direct drive	Muscle/tendon
Simple linkages	-	Non-linkage-snake
Discrete DOF	-	Continuous-no joints flex
Simple joints rotary/slide	3 roll flex joints	Flexible joints
Conventional bearings-friction poor performance	New discrete bearings	No discrete joints
Limited repeatibility No absolute accuracy	Some ABS Accuracy	Controlled to micron level
Limited work envelope	More flexible	Greatly improved mobility
Kinematics computational burden	New chips introduced	Real-time high speed computation
Dynamics not considered in control systems	Dynamics included and force programming etc.	Tuned dynamic behavior

New players and funders are:

NSF	Stanford	CMU
ONR	Univ. of Florida	Martin Marietta
MIT	Lehigh	J.P.L.

This is not enough.

Locomotion - Most robots are fixed in place, on track, on table, or on robo-gate. Some ride on carts and robo-carts can follow wires/painted stripes. They do not navigate but use freeway system. Research is underway at JPL, Ohio State, RPI, CMU, . . . on wheeled and walking robots, even hopping robots. Odetics recently displayed a "functionoid" or walking table. But progress has been slow.

CURRENT	NEAR-TERM	FAR-TERM
Single arm fixed base	Multiple arms	Coordinated arm/legs
Fixed location - wire guided track	Wheeled navigation control area - limited walk	Mobility/navigation semi-controlled environment
Operate in controlled area not self contained	Packaged for broader scope- not self contained	More freedon and self contained

The push is mainly from NASA, undersea operations, some nuclear work - no concentrated funding.

End Effectors - Robots that use hands designed for the application are expensive and restrictive. Two research areas are being actively pursued; quick change hand and dexterous hand. Also, important work on sensor based hands is on-going.

CURRENT	NEAR-TERM	FAR-TERM
Grippers and tools open/closed on/off	Served force and simple sensors - tools for robots	Continuous motion - complex sensing control
Manual change/adjust	Automatic quick change adjust	Rapid change tools/fingers
No dexterity	Limited new DOF hands some 3 fingered	Robot fingers

Key players are:

Stanford	Univ. of Florida
MIT	Vendors
Rhode Island	Large Users
O.N.R.	Air Force ICAM Program

Sensor Systems - Vision systems can be used for ID objects/verify situation, locate and obtain orientation, simple inspection, visual serving, navigation, and complex inspection. There is a wide set of players and commercial systems for first three tasks.

Special purpose systems for bin picking, per inspection have been introduced. Work is underway at University of Maryland, MIT, Bell Labs, JPL . . . on new chips that can bring more powerful vision to the real time robot domain. Still others are working on true 3D vision using stereo, structural light systems, and range finders.

As vision becomes more complex, issues leave sensor domain and enter more AI problems.

Representing shape knowledge

Reasoning about spatial relations

Understanding data imperfections

Interpreting stereo and motion data

Understanding the interaction between visual data and other sensors, models, etc.

CURRENT	NEAR-TERM	FAR-TERM
Binary & special purpose & slow	New-chips edge image gray-scale more fractures	Rapid-broad class of objects
Rudimentary 3D Systems	Depth maps but noisy + in controlled environment	New hardware reliable, able to track moving objects and gather data
	Limited visual serving	Visual serving routine

Taction (Feeling) sensors are of the proximity touch/slip, force torque, or shape ID type. Robots are now appearing with simple sensors for taction. Progress has been slow and only limited usage appears to date. Draper labs pioneered the RCC and the IRCC, IBM and others have put sensors in the fingers.

This area has only recently begun to be attacked for robots. Leon Harmon at Case has done some excellent surveys. Research is on-going at Case, MIT, JPL, CMU, Stanford, & Delaware. Also, at GE, ASTEK, IBM, Lord Corporation and others. A funding focus is needed.

CURRENT	NEAR-TERM	FAR-TERM
Limited one to three element finger sensors	16X16 Array of taction elements	Better resolution + sensibility
RCC & IRCC only recently introduced	Force sensing wrists & other joints - elementary new pro-ramming techniques	Well established & interioring force sensor technology

Control Structure & Programming - All of the prior topics impact this area. Further, there are significant advances in software and control rapidly on the way. The roundtable discussion and robot languages concept and development will cover this area in depth. There are six levels of control. These are:

(1) Servo control with feedback

(2) Coordinate transformation

(3) Path planning

(4) Manipulator/motion language commands

(5) Structured interaction with data bases, complex sensors, controllers, people

(6) Task programming

Levels 1-3 are common in most robots, level 4 is a first generation language, level 5 is both incomplete in the market and in research, and level 6 occurs only in research.

Key questions at level 4-6 deal with:

Robot Independence	Data Bases
Complex Sensors	Hierarchial Control & Integration
3D Data	Higher Order Systems
Human Interface	A.I. Applicability

CURRENT	NEAR-TERM	FAR-TERM
Levels 1-4 common	Structured & Integrated language (level 5)	Task language (level 6)
Rudimentary graphical input, teach language	Robot/Manufacturing Work Station introduced still rudimentary	Advanced
User control of low level interactions	Operating system functions	Automatic
No standard interfaces	Some progress	Well defined
Graphical geometrical layout	Using geometry	Geometrical reasoning
	Limited artificial intelligence techniques	Expert systems & assistants
Simple simulation	Limited physical models	True simulation

Robot software/control is being pursued by many - but leading vendors. IBM, Automatix, GCA, GE, Westinghouse . . . are doing research as well as SRI, MIT, Lehigh, University of Michigan, CMU, Stanford, and at many foreign locations.

Robot Technology and Human Factors

John E. Taylor

Human Resources Research Organization

The presentation consisted of two parts. Part I included the results of a HumRRO study of the experiences of five manufacturers and five users in the general phases of robot installation - before, during, and after. Reasons for success and failure were delineated. Part II outlined several salient training problems and a general approach to their solution. The presentation included a discussion of the impacts of high technology on organizations. The discussion summarized several general finds that have come out of behavioral and social sciences research on the effects of high technology. It concluded with a recommendation for meshing robotic hardware technology, with human/social behavioral technology to solve problems in productivity and industrial innovation.

STUDY OF ROBOT IMPLEMENTATION PROCESS

PROCESS TIME LINE →

	BEFORE	DURING	AFTER
ROBOT MANU-FACTURERS			
CORP. USERS			

FINDINGS TO DATE

BEFORE

ROBOT MANU-FACTURERS	• CUSTOMER KNOWLEDGE • TYPE OF ROBOT • DESIGN ASSISTANCE • USE OF SPECIALISTS
CORP. USERS	• INITIATOR • SOURCE OF ROBOT • INVOLVEMENT OF PERSONNEL • COMPANY READINESS • USE OF SPECIALISTS

DURING

ROBOT MANU-FACTURERS	• INTERACTION WITH CUSTOMER • MID-PROJECT CHANGES • FACILITIES READINESS • INVOLVEMENT IN HUMAN-RELATED PROBLEMS • TRAINING SERVICES & MATERIALS • CUSTOMERS' EXPECTATIONS
CORP. USERS	• MEETING OBJECTIVES • RESISTANCE • TRAINING PROBLEMS • MANAGEMENT FLEXIBILITY • WORKER ADAPTABILITY

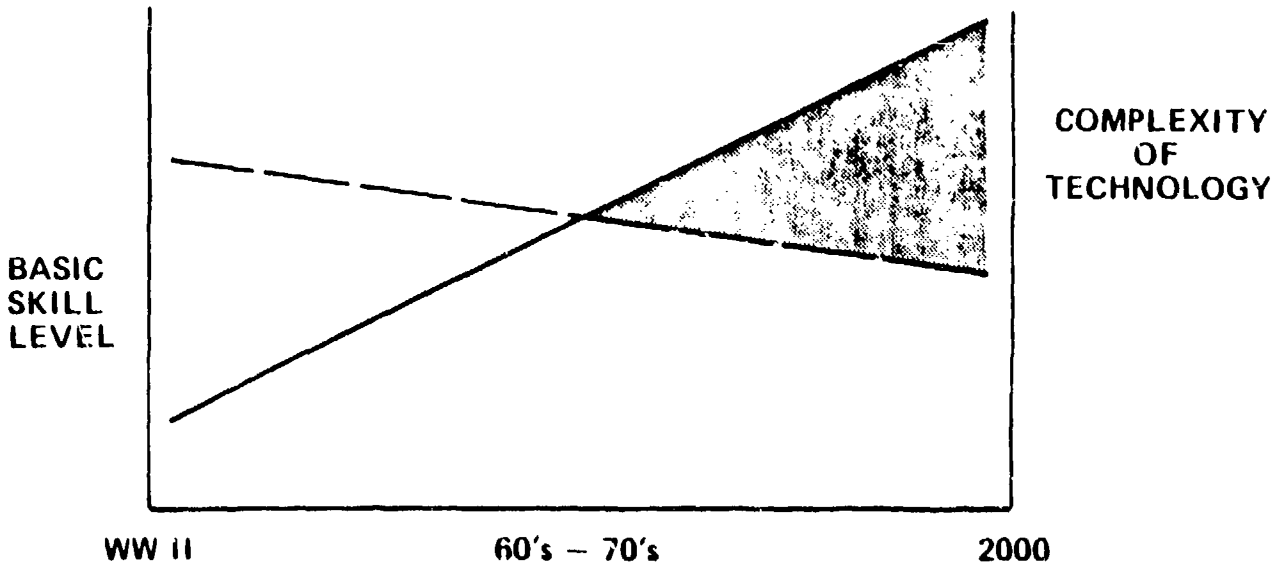
AFTER

ROBOT MANU–FACTURERS	• PERFORMANCE DATA • ABANDONMENTS – ACCEPTANCE – PRODUCT CHANGES – USER EXCESSES
CORP. USERS	• ACCEPTANCE – MANAGERS/SUPERVISORS – WORKERS • PERFORMANCE • FUTURE PLANS

GENERAL OBSERVATIONS

- FRONT-END ANALYSIS
- LOW USE OF SPECIALISTS
- LEARNING CURVE
  - RESISTANCE
  - ORIENTATION/EDUCATION
  - UNION INVOLVEMENT
- JOB/SKILL TRAINING
- PROBLEMS
  - HARDWARE
  - PEOPLE

A GROWING PROBLEM



IMPACTS OF HIGH TECHNOLOGY

- COMPLEXITY
- JOB CHANGES
- CENTRALIZATION
- JOB SATISFACTION
- PROFESSIONALIZATION
- SOCIAL INTERACTION
- COMMUNICATION

TRAINING APPROACHES

Conventional Training	Performance Training
Classroom	Job context
Knowledge information	Job skills
Knowledge tests (70%)	Performance tests (Go-No Go)
Passive lecture	Active practice
Lockstep	Self-paced
Instructor centered	Trainee centered
Infrequent feedback	Frequent feedback

NEVER FORGET

- Successful Technological Innovation Takes Time, is Hard Work, and Pays Off.
- People Problems are the "Achilles Heel."
- Murphy's Law Never Sleeps.

(From a presentation at the 1979 Engineers Public Affairs Forum.)

Our Weakening Trade Position in Manufactured Goods: A Commentary on Mechanical Technology

By Delbert Tesar
Director
Center for Intelligent Machines and Robotics
Mechanical Engineering Department
University of Florida

TRADE

Purchasing power of the dollar is down by more than 50% since 1965. Imports of non-manufactures show a relentless growth capable of major damage to our economy.

Trade in manufactures experienced a $20 billion boost in the period of 1972-1974. The balance became marginal in mid-1978 and distinctly negative for all of 1978 (−$9.5 billion). There exists a "hidden technology deficit" due to the 1972-1974 boost of approximately $30 billion. The trend on deteriorating trade in manufactures was evident by 1968 at which time our investment in R&D also leveled off.

Seventy-five percent of our trade in manufactures is essentially mechanical in nature. The balance in mechanical manufactures was a deficit of $5 billion by 1972, experienced a $14 billion boost in 1972-1974, and then become distinctly negative by the end of 1978 at the level of minus $5.5 billion. There exists a "hidden technology deficit" due to the 1972-1974 boost of approximately $20-25 billion in Mechanical Manufactures. The trend on deteriorating trade in mechanical manufactures was evident before 1965 and definitely quite dominant by 1970.

Trade in heavy machinery has been positive over the past 15 years but has experienced a $5 billion deterioration in the past two years. Light machinery has been consistently negative since 1964 and now shows a $10-12 billion trade deficit in 1978. The field of aircraft remains strong although the European consortium and the Japanese have put us on notice that they intend to invade that market. Cars and trucks are nearly a disaster. Virtually no academic research is ongoing to directly support the manufacture of vehicles. The loss for 1978 was $10.3 billion. Chemicals are expected to remain strong because of a widespread R&D activity. Electrical systems are also expected to remain strong for the same reason. Chemicals and electricals benefit from 40% to 60% of our domestic R&D expenditures. They represent, however, less than 25% of our trade in manufactures. Mechanical technology which represents nearly 75% of our trade gets surprisingly little (approximately 0.7%) of our non-defense oriented federal R&D budget. Japan expects a 1978 surplus in manufactures of $63 billion, that of West Germany is $49 billion, while the U.S. shows a $9.5 billion deficit. Yet, the energy self-sufficiency is just the reverse—5%, 40%, and 75%, respectively. The 20 most negative trade categories closely associated with mechanical technology generated a $34 billion deficit in 1978, and it is worsening rapidly.

PRODUCTIVITY

Following is a break-down of the ingredients in generating productivity during the past 40 years in the U.S.:

Technology	38.1%
Capital	25.4%
Labor Quality	14.3%
Economies of Scale	12.7%
Resource Allocation	9.5%

(E. Denison, Brookings Insitute, 1978)

This shows that technology is dominant in protecting our standard of living.

Over the past 15 years, our Western trading partners have all had higher annual productivity growth than the U.S.:

Japan	10.5%	France	6.0%
Netherlands	7.5%	West Germany	5.8%
Sweden	7.1%	Switzerland	5.3%
Belgium	6.5%	Canada	4.3%
Italy	6.4%	United States	3.4%

From 1970 to 1977 the accumulated increases of productivity also show the U.S. lagging:

West Germany	46%	Canada	25%
France	42%	United States	21%
Italy	38%		

Labor Department figures show that productivity in the non-farm sector grew only at 0.6% in 1978. Council of Economic Advisors now suggests productivity growth in the non-farm sector is not more than 1.5% per year up to 1985. Dr. Alice Rivlin, director of the Congressional Budget Office, estimates that real GNP growth for 1979 will be between zero and 2%. Latest Department of Commerce figures show that the rate of growth of our Gross National Output is declining: 1976—5.7%, 1977—4.9%, 1978—3.9%.

R&D COMMITMENT

About 50% of our national R&D is used to support manufacture. About 83.5% of our federal R&D budget goes to electrical and aircraft manufacturing endeavors. Only 1% of NSF's R&D budget goes to mechanical technology, the base of more than 70% of total trade. Precedent for university-sponsored federally funded research and development contracts exists of which the top ten average $125 million per year each. Only 7% of engineering basic research is mechanical of which at least half is in the thermosciences. Engineering represents 9% of the total federal basic research effort and mechanical engineering represents only 0.6%. Machinery R&D (both federal and industrial) represents only 6% of the national total to protect 60 to 70% to our trade. Machinery and textiles receive only 0.7% of the federal R&D budget for manufactures. Federal funds support only four percent of the machinery R&D, yet it supports 40% of the electrical and 77% of the aircraft and missiles R&D. Interestingly, 50% of our limited machinery R&D goes into office machines which represents only 3.3% of our manufactures trade.

INVESTMENT

Annual investment of capital per worker shows the U.S. is lagging:

	1967	1973
West Germany	$298	$693
Japan	$191	$324
United States	$258	$220

Percent of Gross Domestic Product invested annually in plants and equipment also shows the U.S. is lagging:

1947-1967 ....3.0% 1973-1977 ....1.3%
1967-1973 ....2.5%

Latest Commerce Department figures show that new orders from non-defense capital goods (plants and equipment) declined 7.4% in November 1978 and 3.8% in December 1978.

Rate of savings per unit of income is 3 to 4 times lower in the U.S. than Europe and Japan and that rate in the U.S. has been declining.

1976 .... 7.5%
1977 .... 5.1%
1978 .... 5.3%

BASIS FOR THE SOLUTION

In Japan, the research and development efforts of universities, government, and industry are closely linked to large-scale industrial ventures destined for commercial application. Considerable support is given to new manufacturing technologies. The West Germans have been doing the same for two decades. Canada now is establishing five technology and innovation institutes.

Simon Ramo of TRW says that the bottleneck is not science and technology per se but in the arrangement process among government, private enterprise, and science and technology. In fragmented industries, no single firm can introduce certain critical operational changes; the cooperation of many others, both within and outside industry is needed.

The lack of close relationships between engineering schools and manufacturing industries also impedes the technological innovation process—a barrier not present in some of the major competitive countries.

The Cooperative Agreement Act of 1977 (signed February 1978) was established to enhance government, industry, and university cooperation by:

1. Strengthening the existing processes for grants for basic research and procurement for specific federal needs by defining a separate and distinct process for assistance.
2. Creating a new pathway (or pathways) of assistance which would enable the rapid, controlled diffusion of developing technology to industry so that it can create new innovative technology and, hence, products and services for the marketplace.

Assistance processes will yield results only when industry participates in the formulation of priorities and commits sharing risk capital to meet agreed upon goals. R&D performing institutions must be effectively linked to those institutions that actually produce and deliver goods and services, whether in the public or private sector, if the assistance of innovation is to be effective.

Fostering the adoption and widespread diffusion of new technology presumes that federal officials possess the knowledge of market factors which govern this diffusion. Many existing agency support programs suffer from a weakness in this key management responsibility. President J. F. Bucy of Texas Instruments notes that:

> "One striking difference between engineering education in the U.S. and West Germany is the production of engineering graduates for careers in manufacturing. This tradition is well established in Germany and weak in the U.S."

SOLUTION

Since about 75% of our trade in manufactures is associated with mechanical technology and since very little federal agency activity now exists in the United States by comparison with other countries, it is recommended that:

- A cohesive and structured national program for mechanical technology and manufacturing be established.
- Ten centers attached to geographically distributed universities be formed as the focus of the following technologies: 1. Light machinery; 2. heavy machinery; 3. manufacturing processes; 4. industrial robots; 5. human augmentation and prostheses, 6. remote robotic systems; 7. artificial intelligence; 8. electro-mechanical components for intelligent machines; 9. tribology; 10. engineering economic and human factors.
- Heavy participation of industrial governing boards should guide the missions of each of these centers for the appropriate class of technology.
- There be heavy involvement by the federal agencies, initially, perhaps with as much as 75% of the funding.

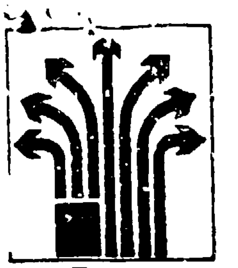
  This funding would reduce to a residual level of 25% to maintain a centralized control and oversight function.
- The state or local region should provide land, buildings, and a constant level of 25% funding because the geographical region would be an immediate and continuing beneficiary.
- After a period of operation (perhaps five years and not more than ten years), the center would be required to bring in 50% of its funding by direct negotiation with interested industrial parties and groups of industries seeking solutions of real technological problems.
- The educational role of the centers would be substantial in keeping practicing engineers and scientists abreast of the latest developments in the mission area no matter where these developments occurred in the world.
- Each center would have specially trained management intimately aware of needs by participating industries of the mission area.

Technical Opportunity for Light Machinery

The industrial sewing machine Consew (produced by Toyota of Japan) runs faster, is more reliable, has four times less downtime for bobbin interchange, and costs 25 percent less than a similar U.S. machine. Another example involves a new tobacco manufacturing plant in Georgia which is the third largest in the U.S. All of the machines are of Italian, German, or English origin and are maintained by foreign craftsmen. The plant manager confirms that appropriate U.S. technology did not exist in 1976 to fulfill the specifications for competitive machines.

The U.S. failure in electronic cameras. The electronic camera contains sensitive electronic sensors that detect levels of light and transmit this information to a digital micro-processor, which then automatically sets the f-stop and shutter speed. The precision built into the machine comes from the intricately designed mechanical shutter which typically moves at 4 meters/second. The electronic controller must release the first shutter or curtain and then release the second or closing shutter within an allowable error of 1/10,000 second. The 1978 trade loss in cameras was $496 million, ten times the total NSF engineering research budget. The nature of this technological deficit is further highlighted when it is realized that all precision camera systems for aerial photogrammetry are now imported.

The U.S. failure in entertainment electronics. Television and radios show a trade deficit of $2.77 billion. Not only is this deficit worsening rapidly, but the ratio of imports to exports is four to one in televisions and 15 to one for radios. It is well known that Japan and other Far East countries have been able to accomplish this by having not only higher level electronic technology but also superior manufacturing quality. Much of the manufacturing quality is due to improved machine precision and automation in the component manufacture and the chassis assembly, both of which are dominated by light machinery technology. They intend to invade our markets in computers and micro-electronics (already marginal in trade) which today represents a $41 billion business within the U.S. Our inability to develop technology for quality mechanical manufacturing may prove to be our Achilles' heel in this economic confrontation.



This intimate awareness is essential to enhance the required negotiations in the formulation of the assistance plan, in the performance of the task, and in the assessment of the results for further distribution.

- It is necessary that each of these centers represent a critical mass of principals capable of meeting the m... ed needs of industry. It is suggested that 50 principals and 100 support personnel would be warranted for four to five of the centers and about half that for the others.
- The prestige, effectiveness, and focus of these centers would be enhanced by a meaningful financial base. Hence, a total program of $100 million/year is recommended. This represents only 1% of our yearly loss in light machinery and its products alone. To do less is not to face the problem which is an increasing deficit already exceeding $20 billion/year and potentially much greater.

Since technology represents about 40% of our productivity base, concerted activity at this time is essential to prevent a further worsening of our technology gap. No action now will result in a much greater tax on our people which last year cost them 2½% in their standard of living.

Not solving this problem means that more jobs will be shipped out of the country, the decreasing value of the dollar will accelerate, clean light industry will be built in other countries, and the corrective pressures on our technological institutions to take compensating measures will decrease.

...ATURE OF MECHANICAL TECHNOLOGY

Two ... technical opportunities. Two major opportunities face the industrial community. These are (1.) the development and use of modern research and design tools to establish a resurgence in the fundamental field of machine science and (2.) the full use of distributed electronic sensors and computers combined with mechanical production devices to create more effective production systems.

Machine science is basic. Many designers have given up on our weakened mechanical technology. Since mechanical operations are mandated by human existence it would, however, be appropriate to treat the science of machines as fundamental in its ... ght and then augment its application with every feasible co... on of electronic sensing and control. This is the major opp... ity facing light industry today. It is clear that our competing industrial countries are already pursuing this opportunity. If it is energetically pursued by the U.S., a new generation of machines could evolve to reestablish the relative vitality of American industry.

Light machinery design. Light machines generally employ highly geometric devices of numerous parameters that require sophisticated or high technology design procedures to achieve optimum results. The designers of the steam locomotive spent their lives perfecting the complex valve control linkages. In many ways, today's designers frequently develop machines by the same trial and error methods, with a remarkable expenditure of time before a usable machine is obtained. An effective machine science augmented by modern computer interactive programs would drastically reduce this design-to-product cycle time.

Character mechanical systems. Mechanical devices can create large repetitive forces, provide precision at high speed, consume ... little energy, have a long life with high reliability and generate ... no noise. Unfortunately, such systems based on cams, gears and linkages are highly non-linear multi-parameter systems whose design is only partially understood. These systems may easily contain 50 independent design parameters making their optimal design a major unsolved task.

Weakness in machine technology—why? Work on machine science has been ongoing in Germany for 100 years. By contrast work of this class began in the U.S. only 25 years ago. During the first half of this century, companies hired expert designers from central Europe to compensate for our own inactivity. Consequently, little pressure developed on the universities to provide excellence in education of technology in this field. Even during the funding heyday following Sputnik (1957), the machine community did not respond and thus benefit from a surge of activity as did other technologies.

Nature of Robotic Technology

Intelligent machine. The integration of sensors, computers and adjustable mechanical structure would create an intelligent machine capable of perceiving the environment in which it exists and making an appropriate response. Today's example is the electronic camera. Tomorrow's opportunity could well be a full spectrum of robotic devices to assist the surgeon or to do remote maintenance in hostile environments. The micro-electronics revolution has produced a $41 billion-per-year industry and has created 100,000 new jobs. Its effectiveness will increase immensely when micro-electronics are coupled with versatile mechanical devices to make intelligent machines. Because of the weakness of mechanical technology, this is taking place either rarely or not at all.

The robotic system. The robotic system is in many ways the technological equivalent of the human system, having components such as sensors (eyes), actuators (muscles), and a computer (brain) which allow the system to perform mechanical functions by reacting to needs in its environment that it perceives and interprets. Such systems are of particular economic importance to the pressing problem of remote maintenance of nuclear systems. Complex robotic systems are not completely controllable by a human operator; his role must be augmented by digital computation. This will be one of the most demanding engineering problems yet to be fully addressed by the machine science community in the U.S.

Applications of robotics. Other applications for robotics are: Offshore oil well drilling and maintenance, coal mine accident, missions deep submergence vehicles surveillance in the ocean, on land, and in space; micro-surgery human augmentation for manufacturing prostheses for the handicapped, industrial automation and assembly, removal of operator from hostile environment.

Robotics as catalyst for machinery development. Since robotics is an emerging technology of great interest, it could become the vehicle for technological development in the whole field of mechanical design science. It is expected that as more electronics are integrated into basic machines and as robotic devices are more widely applied, a general blending of the whole spectrum will occur. Because every mechanical function of the robotic system must be electronically controlled, the robotic device will perhaps represent the ultimate marriage of these two technologies.

Are robotic systems needed? It has been shown that the 1978 trade deficit associated with the worst 20 deficit generators in mechanical technology was $34 billion. Are robotics technology and its supporting scientific and industrial communities going to face a similar fate? Can our defense posture be maintained without the highest quality in this technology? It may be argued that measurable economic and m... y weakness will result unless government leadership now takes steps to create the foundations for a concerted national robotics program.

Significance of the robotic system. It is generally accepted that the robotic manipulator has the same relative importance for mechanical systems as the digital computer has for electrical systems.

AD-P003 998

CURRENT SUCCESSFUL ROBOTICS APPLICATIONS

AUTOMATIX

BY: VICTOR SCHEINMAN

Automatix is a company engaged in the Robotics Systems Business. We make systems rather than just robots. In fact, at the present time, Automatix does not make any of what one might call the traditional robots...the mechanical manipulation mechanisms. Instead we make just about everything else; the controllers, the positioners, the fixtures, the sensors, the software, and the factory floor interfaces. In general, we deliver all of this, with robots, as a turnkey package to the customer.

We like to think of robot mechanisms and all of the equipment which interfaces to the factory and the user as terminals of the system. At the heart of this system is the controller and its software. It is in this area where we have centered our product development efforts. During the past 3 years and in the future, most of the increases in robot capability will come from controller and software advances rather than from specific mechanical or device improvements. We see advanced capability as being something which is programmed in rather than built in, and this is what we feel really marks the difference between machine automation systems and robotic automation systems.

Like most other companies in this business, we have a big picture view of robotics. But robotics is not just big pictures, its working applications, and that's what I'm here to talk about today. In fact, although its the big installations of spot welding lines and spray painting in Detroit, and automated motor plants and video cassette recorder assembly lines in Japan which get the headlines, there are literally hundreds and hundreds of smaller installations involving one to 5 robots, some sensors, and a cell or system controller at hundreds of locations throughout the United States. In fact there are some simple robot arc welding installations at small firms having as few as two people. In my talk I'd like to touch base on a few representative system installations, and try to come up with some comments about each one of them.

Arc welding is probably the easiest application of robotic systems to understand.

Steelcase, a large office furniture manufacturer, produces a line of welded steel rod chairs. They wanted a welding system which would not only produce good quality, meaning strong welds, but also good looking welds. This

multistation system served by one robot and one person meets their needs. An example is one robot working on different parts of a chair at several stations. While the robot is welding at one station, parts are being jigged at other stations. In this way, the robot welding speed and versatility is properly matched to the task.

Raytheon, a military electronics contractor, produces shipboard weapons systems. They have need for a large variety of different shaped heavy gauge aluminum boxes, cabinets and containers. Often production runs are short. Their welding system consists of a single robot, and a two station, three axis welding positioner with a large fixture plate drilled with a pattern of mounting holes. Jigs can be quickly set up, or parts even fixed directly to the surfaces. Programming the robot from the teach pendant, using high level commands and built in weld schedules is extremely rapid, and nearly goof proof. The advantage of the use of weld schedules is that many welds can be programmed by people who are not expert welders, as all weld parameters such as wire feed speed torch speed, current, etc. are set by a single high level software command which can be made from the teach pendant.

Simple installation in a heavy plate steel fabricating plant is easy. All it takes is a robot, a plasma cutting torch and a program. What makes this installation exciting is that it's hooked up via a CAD/CAM link to a CAD system. The cuts are either programmed and visualized on a terminal, or determined directly from part drawings in the system data base, then cut with this system on an as needed basis.

Robotic assembly is the big field people have talked about, many research and development labs have tinkered with, but few really successful industrial applications have been developed. Everyone has their concepts.

Digital Equipment Corporation used to stuff computer keyboards by hand. Assemblers would take individual keys from bins and insert them. Although they could assemble a board of about 80 keys in as little as 3 minutes, the error rate was high, especially when running one of the more than 100 non-standard layouts DEC offers for use around the world. Users don't like to have two "A" keys, or interchanged key logos, or even a scratched key on their new terminal. This system features two stations.

The first station looks like a conventional part feeding and sorting system. Instead of specially made bowl feeders and mechanical sorters, these traditional hard tooled mechanisms are enhanced by artificial vision inspection stations. They check and select for the proper logo, correct orientation and visual defects.

The sorted, oriented and inspected parts go to an assembly station where they are assembled by a robot mechanism. Using compliance elements in the multiple vacuum grip fingers, they can be inserted 2, 4 or 8 at a time, for a total time of about 30 seconds per keyboard.

What's interesting about this example system is that the entire system is regulated by the same controller which processes the visual images of the keys. The programming language is user oriented and enhanced with over 3,000 lines of messages, help information, diagnostics, reprogramming aids, and general advice on just about anything one might want to know or do with the system. So although delivered as a turnkey assembly system the user has the ability to modify or completely change the keys.

Another interesting observation one might make about this system is the robot. I think that the general concept of the robotic automated factory is that of a place with just robots, machines and material all running smoothly. There ae already a few such examples, primarily in Japan. But in general, the true robotic content of a robotic automated installation averages about 20-25% on a cost basis at the present time. The rest is accessories such as conveyors, feeders, grippers, and positioners, and job specific components such as fixtures, jigs, and tools and the engineering and programming and setup and debug and travel time and expense. So your cost guidelines when thinking about robots should be the overall system cost rather than the cost of just the robot mechanisms. A low cost robot doesn't necessarily produce a low cost system.

The Westinghouse Defense Electronics Group in Baltimore, Maryland has been working with a robotic electronic component assembly system. This system is an example of an application where speed does not matter too much, but reliability and quality of workmanship is paramount.

Westinghouse builds specialized military electronic circuit boards. They must stuff these boards with a collection of standard and nonstandard components. The typical batch run is about 20 of a kind. This is too short a run to set up conventional insertion machines, and the error rate of manual assembly is unacceptably high, so they are using a robotic insertion and inspection system to improve product quality.

A robot part positioner, an artificial vision station, an X-Y-Z crimp tool positioner, and an Automatix system controller are used at each station. Parts with roughly formed leads are picked up by a servoed gripper with force sensing fingers to control the level of squeeze. The part type and number is visually verified, and the lead position and length is measured by triangulating from several pictures. The robot positioner then positions the longest

lead over its hole and partially inserts it. Next it adjusts the part body to position the second lead over its hole and inserts it. And so forth until all the leads are inserted.

The task is completed by completly inserting the all the leads and individually cutting and crimping on the back side.

The entire process now takes about 30 seconds per component, which although slow compared to the dedicated machine alternative, is still faster than skilled humans, when all the manual process and inspections are considered.

The next few robotics system application examples contain no traditional robot mechanisms at all. But they are truly robotic in that the controllers are the same as for systems with robot mechanisms, they are reprogrammable, and they transport and process physical material. They also have one common theme. They use a visual sensing and general purpose vision sensors in the form of solid state CCD television cameras.

The first example is a system installed at General Motors Corporation. It's primary function is inspection of stamped automobile and truck body and frame panels. Dies occasionally break resulting in missing or misshapened holes. Human inspection is tedious and unreliable when there are many holes without any regular pattern. Frequently, missing or malformed holes are found only after the part has been assembled into a vehicle. By then extensive rework or expensive rejection is necessary.

This system, controlled by a factory floor controller, inspects holes at the rate of over 600 per minute on stamped parts as they move down a conveyor between stamping stations. Multiple solid state cameras image selected scenes with fine resolution, and a single vision processor at each station processes the data. Speed and reliability were important parameters here.

Rejected parts are marked with spray paint for removal or rework, and the source of problem, the exact hole and it's corresponding stamping press immediately identified.

This next example a robotic inspection application in which detailed inspection of many individual features was important to the customer. A finished keyboard is placed into an enclosure. The doors are closed and controlled lighting illuminates the keys. An X-Y positioner steps the keyboard around under a CCD camera. Multiple images are processed, each containing only one or two keys. Letter are checked for correctness, print quality and character centering is examined, the surface is checked for scratches,

and even proper key installation is checked in a process which takes about 30 seconds. The entire process, including detection of which type of keyboard, movement of the programmable positioning of the X-Y positioner, and controlling safety door interlocks is controlled by the same artificial vision controller.

A third example shows the calibration and test of a vehicle instrument cluster. The needle orientation is measured. Indicator lights and their color are also tested and detected.

A fourth vision example shows that very specific tasks can be done with very general equipment. A person, a camera and an ultraviolet strobe light source have been packaged into a machine for inspecting for cracks in connecting rods using the the Xyglo process. The controller is the same, only the program has been tailored at a user level to the application.

It is important to know that we are working with programmable machines, sensors, a computer based controller, and a high level programming language. There is almost no difference between this system and one containing a robot mechanism.

Most of the successful artificial or robotic vision applications to date have been in the area of inspection. But it is in the area of integrated vision or sensor guided and controlled robots where great unlocked potential lies. Many companies are working in this area, and Automatix is among them. I'd like to give you a couple of examples of some first delivered systems.

In the first example the part is a railroad car truck. The installation is for the Norfolk and Western Railroad, and the job is to weld in wear plates inside the truck. They must be replaced at regular intervals and the procedure involves burning out what remains of the old plate, and welding in a new plate. This has been a manual job is not too pleasant. Well, a blind robot wouldn't do the job because each truck is a bit different as the large castings are only rough machined, and the burnout process leaves lips and edges. So a part finding vision system is mounted right on the robot. The two cameras in the pictures of the new plate in place, before welding is started and correct the taught robot welding path to match the specific conditions of this truck.

We also have an example of seam tracking welding. In many cases, especially where flame or large rough saw cut plate material is used the weld seam is not repeatable from part to part. In addition, there is some warping which occurs during the actual welding process. Real time seam tracking is necessary, and that is just what is being shown here. Although factor floor experiments are going on right now, this is not yet a truly turnkey product.

Structured light can also be used which by the way is a very powerful tool. It's used in the form of a shaped plane of laser light emmitted from a welding torch mounted source. The image of the plane is picked up from the torch mounted camera and processed. Torch motion corrections are made at a rate of several times a second.

What I've tried to bring out, in this brief series of application examples representing progressively increased use of sensors and high level information processing is that the future, and ever so much the present is really sensors, software, and systems. In summary, there is more to robotics than just the robot. It's melding of mechanisms, controllers, software and material. In a typical factory floor system, when all is said and done, the robot mechanism is a small part, and the successful installation represents proper considerations for all of the system components.

The Air Force Logistics Command organically manages and repairs aircraft and aircraft components at each of the five Air Logistics Centers (ALCs). Aircraft systems and aircraft components are managed by the Directorate of Material Management at the five ALCs.

Aircraft repair is performed by the Directorates of Maintenance. Component repair is done by Technology Repair Center concept where each Directorate of Maintenance specializes in certain types of repair. For example Sacramento ALC both manages and repairs the F-111 airframe while Ogden Air Logistics Center manages and repairs landing gear components for all Air Force aircraft.

ABSTRACT

ROBOTIC WELDING SYSTEM

by

J. A. Fouse
Manufacturing Technology Manager
Vought Corporation

This presentation discusses an on-going in-house development program to establish a programmable robotic welding work cell for Vought production applications. A flexible welding cell approach as compared to a fixed robot dedicated to a specific part application, is being pursued in the establishment of this welding work cell. The developed system is designed in a manner to assure compatability in future computer aided manufacturing (CAM) operations. The system design includes provisions for future off-line programming, weld seam tracking and multi-station operation. The immediate application of the robotic welding cell is for aluminum welding. The system will be initially qualified for production welding of turret right hand side subassemblies for the U.S. Army Multi-Launch Rocket System (MLRS) launcher/loader. The manufacturing technology project to define robotic welding system requirements, design the work cell and qualify the developed system for production welding of MLRS turret side subassemblies will be discussed in the presentation. The discussion will include problem areas, sensor requirements, potential part applications and benefits expected from robotic welding.

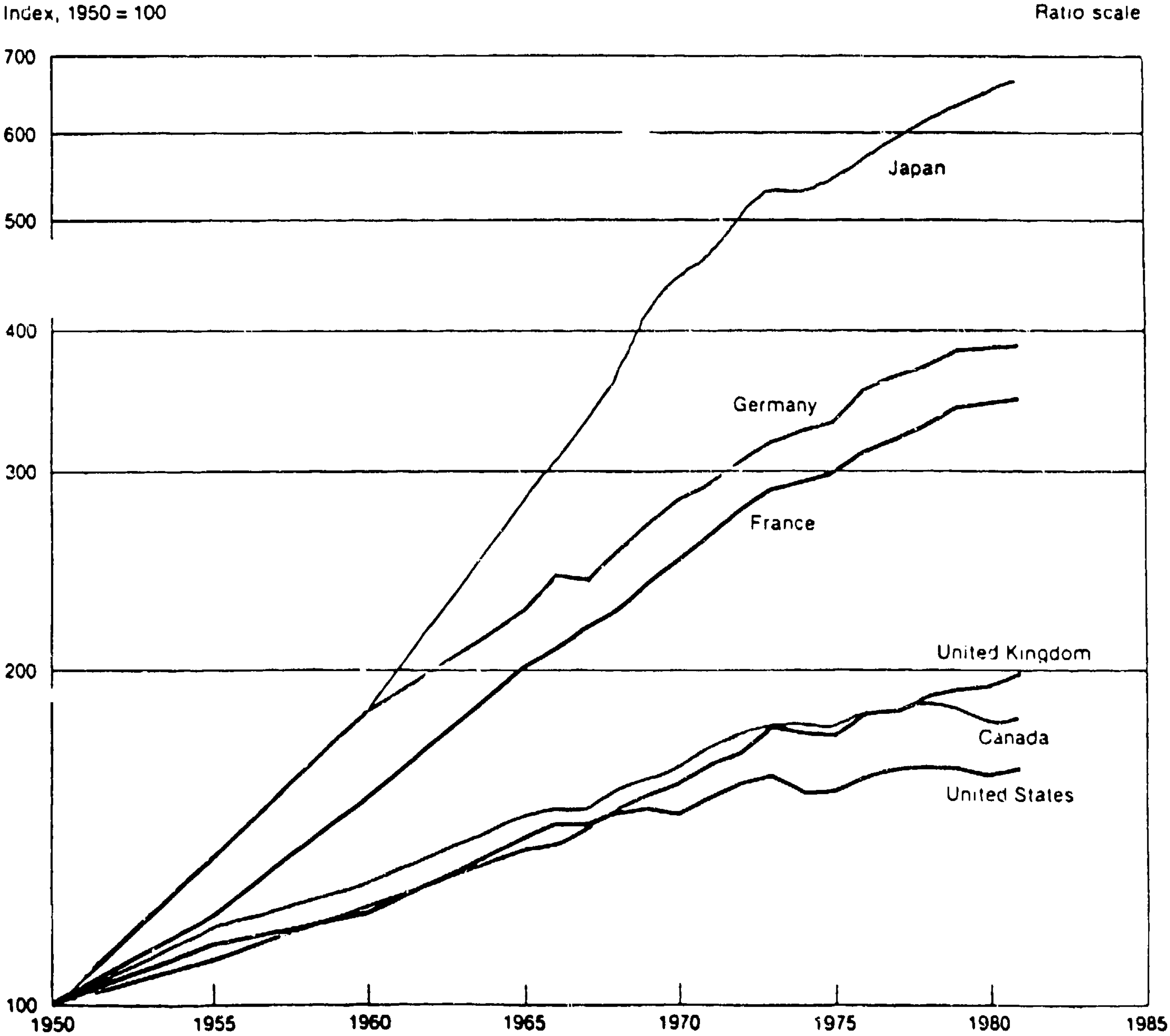
THE FUTURE OF ROBOTICS-WHAT DOES THE NEXT DECADE HOLD?

SCIENCE APPLICATIONS, INC.
BY: T. MICHAEL KNASEL

INTRODUCTION

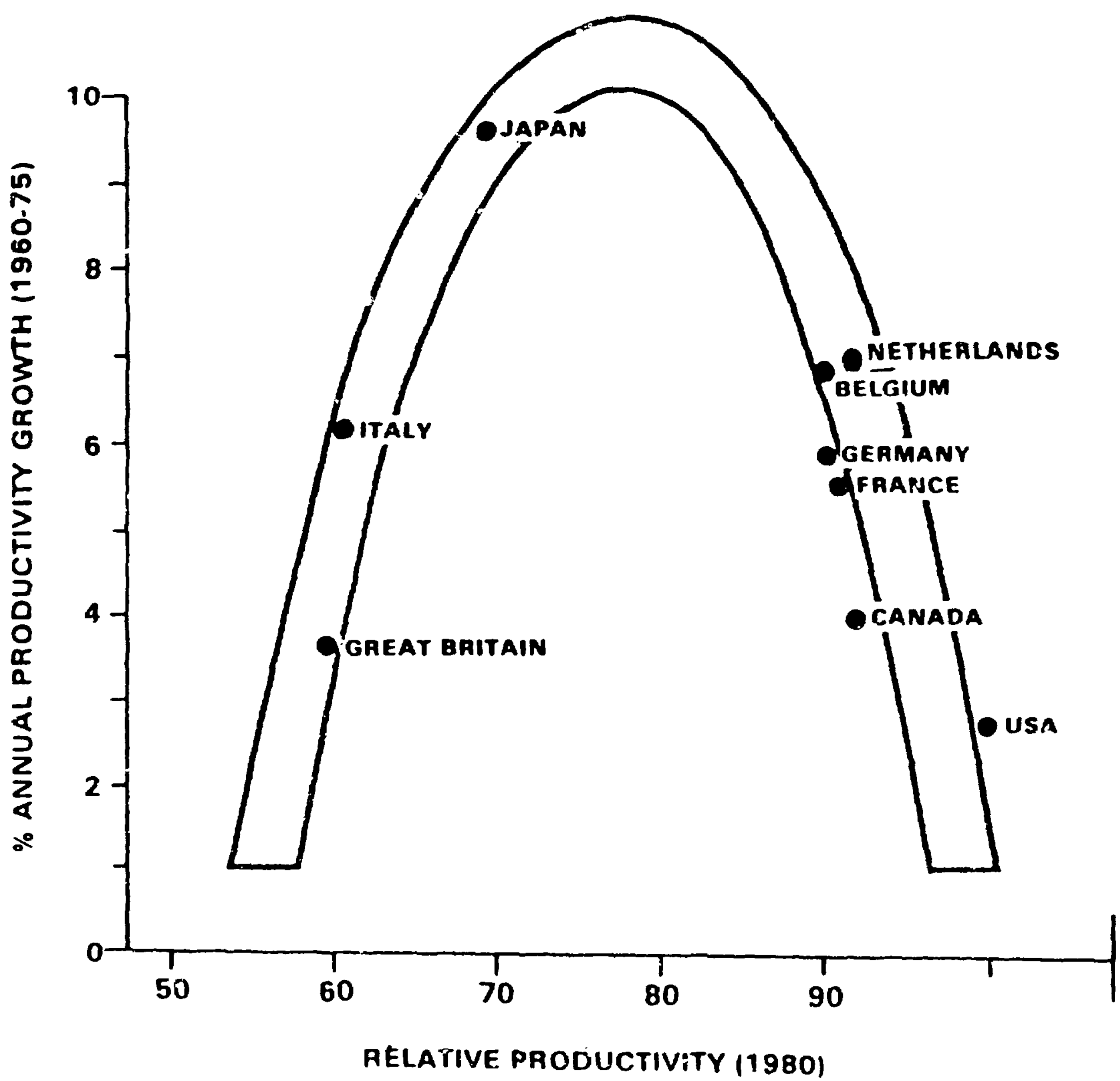
- WORLD MANUFACTURING PRODUCTIVITY RACE--THE TORTISE AND THE HARE
- DOES USE OF ROBOTS CORRELATE WITH PRODUCTIVITY?
- WHY SHOULD DOD USE ROBOTS?

Chart 10.
Trends in real gross domestic product per employed person, selected countries and years, 1950-81



Source. Bureau of Labor Statistics

GROWTH RATE AND PRODUCTIVITY COMPARISON
FOR NINE INDUSTRIALIZED NATIONS



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TRENDS IN INDUSTRIAL USE OF ROBOTS

- WHICH U.S. INDUSTRIES USE ROBOTS AND TO WHAT EXTENT
- TRENDS IN TYPE OF ROBOT PRODUCTS THROUGH 1992
- VENDOR COMPANY SHARE-OF-THE-MARKET

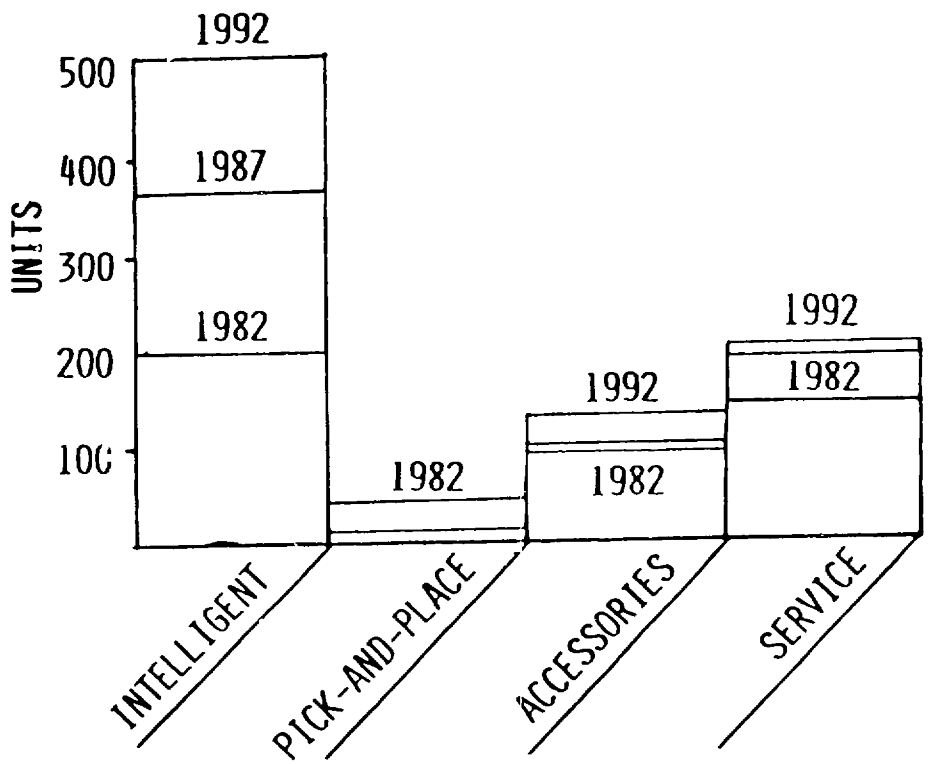
COUNTRY	FIRM	CURRENT ANNUAL SALES ($B)	SALES PER EMPLOYEE ($K)	CURRENT # ROBOTS	ROBOTS SALES (PER $B)
USA	GM	58	77	1200	21
	FORD	37	87	300	8
	CHRYSLER	9.2	99	100	11
	AMC	2.6	122	?	?
JAPAN	TOYOTA	14.7	317	500	34
	NISSAN	13.4	317	650	48
	HONDA	6.0	261	300	50
	TOYO KOGYO	4.5	168		
	MITSUBISHI	4.5 (EST)	200	44	
	ISUZU	3.1	184	50	16
	FUJI H. I.	2.1	158	100	48
	SUZUKI	2.0	229	100	50

USE PROJECTION OF INDUSTRIAL ROBOTS
SUMMARY RESULTS BY 3-DIGIT SIC INDUSTRIES - USA
BASE - 1982 SURVEY RESULTS - 500 FIRMS
FORECAST - SAI PROPRIETARY MODELLING TECHNIQUES

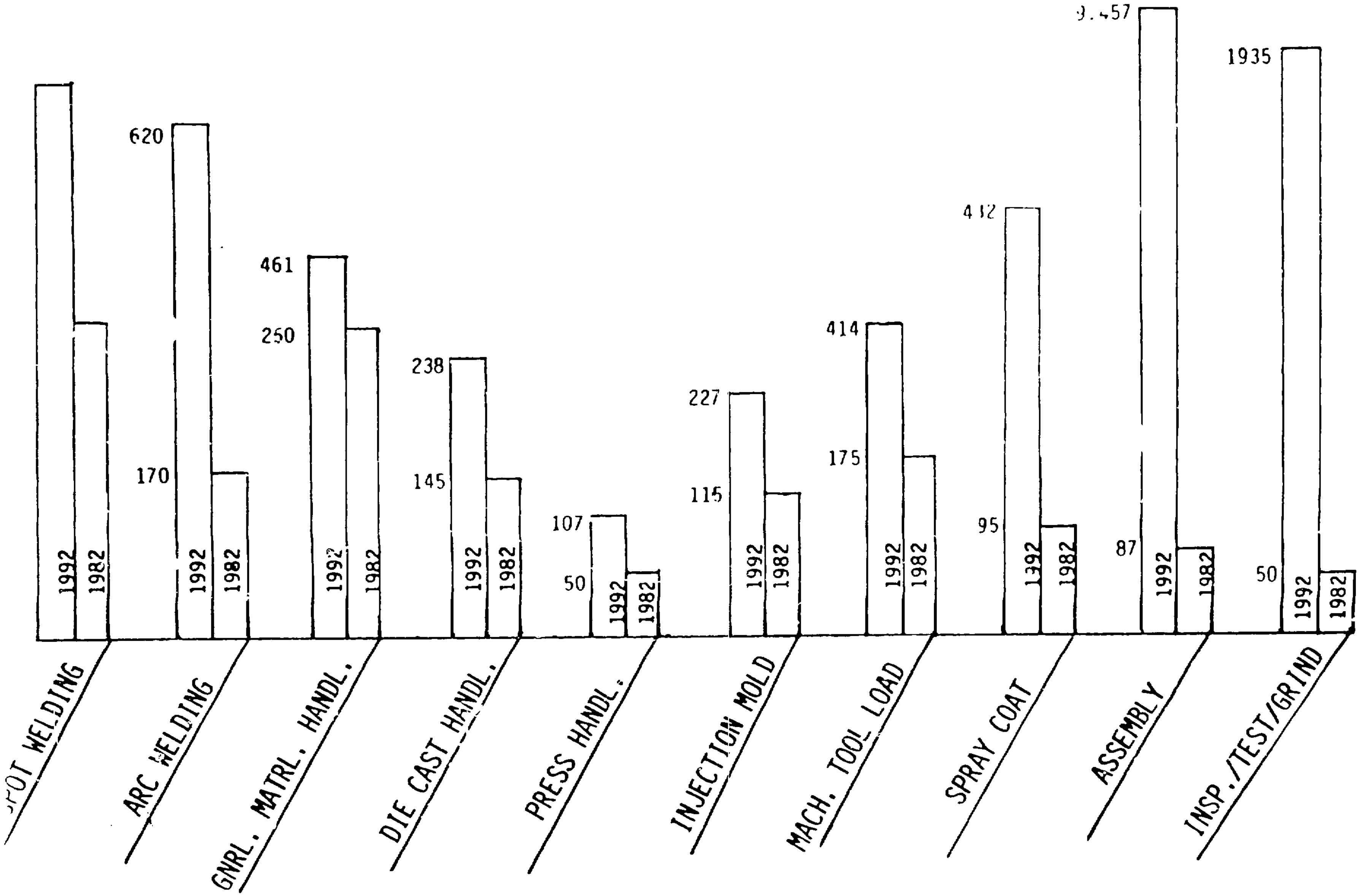
SIC	Name	%Firms That Use Robots	1982 Investment Ratiox10^3*	Annual Growth%	Sales 1982 Units	Sales ($M) Value	Sales 1987 Units	Sales 1987 Value
200-210	Food/Tobacco	15	0.09	46	100	7.0	538	24.4
220-250	Textile/Furn.	42	1.50	20	200	14.0	743	35.5
280-290	Chem-Petro	30	1.00	24	100	7.0	293	14.4
330	Primary Metal	36	0.44	7	100	7.0	140	7.1
332	Die Casting	57	1.88	26	200	24	563	48.7
340	Fab. Metals	15	1.06	28	125	15	397	33.8
260-370	Elect/Elect.	40	.36	27	175	26.2	578	59.1
371	Automotive	59	0.39	32	350	52.5	1689	159.9
372	Aerospace	30	0.51	17	25	3.7	134	11.6
380-40	Instruments/ Transportation	30	.20	29	100	15.0	371	38.1
TOTALS OR WEIGHTED AVERAGES		-- 32%	-- 0.64*10-3	-- 22%	1475 units	$171.4M	5400 units	$433.1M

*Annual investment in robotic equipment divided by annual sales.

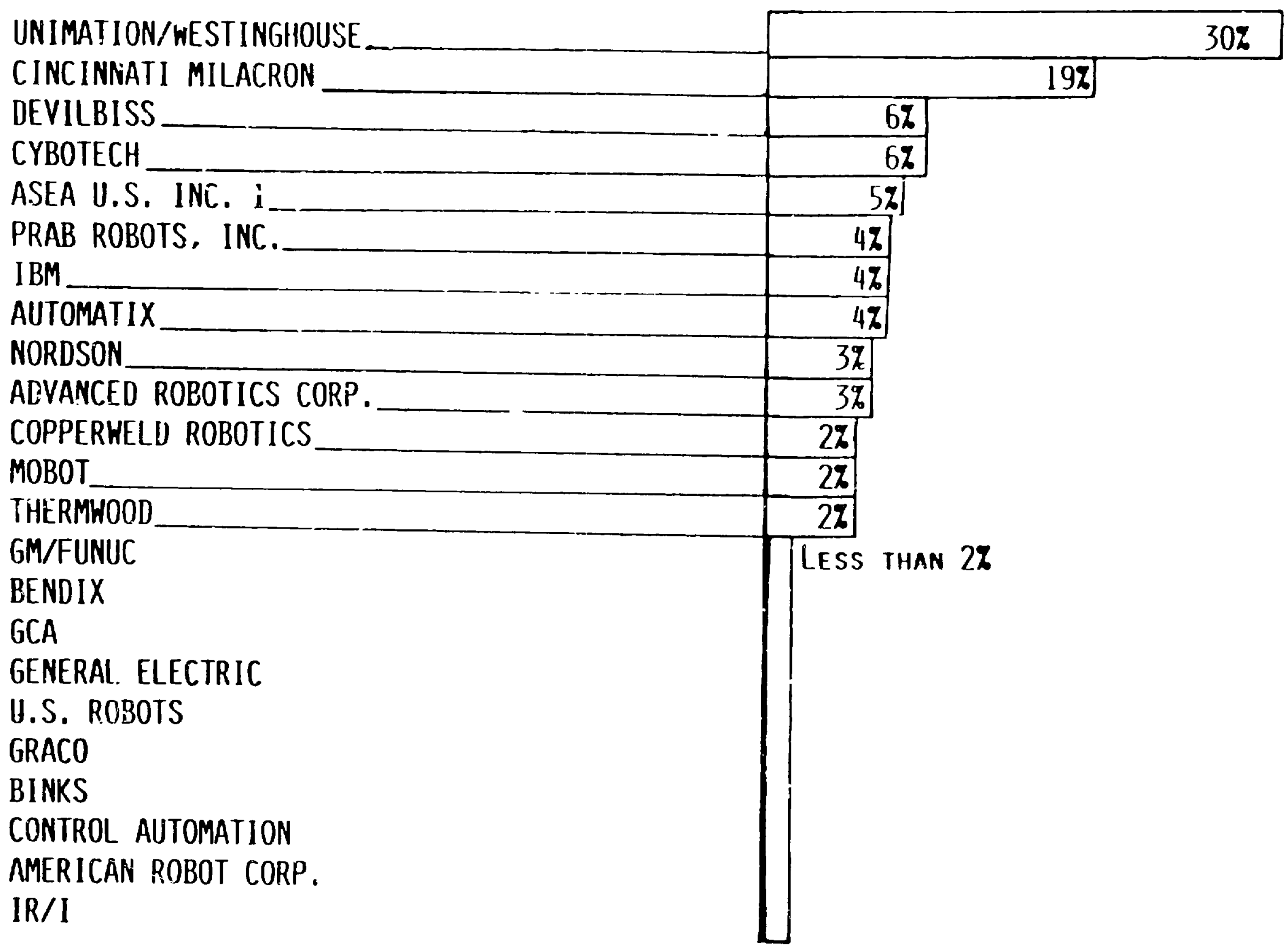
TOTAL ROBOT SALES BY MAJOR BREAKDOWN



ROBOT SHIPMENTS IN UNITS BY APPLICATION CATEGORY



U.S. ROBOT SUPPLIERS RANKED BY MARKET SHARE



U.S. ROBOT MARKET SURVEY-OVERVIEW

- ABOUT 500 FIRMS SURVEYED
- 15 KEY MANUFACTURING CATEGORIES THROUGHOUT U.S. COVERED
- MIDDLE MANAGEMENT DECISION MAKERS RESPONDED
  - INDUSTRIAL ENGINEERS
  - PLANT MANAGERS
  - PRODUCTION PLANNERS
- QUESTIONS CONCERNED LONG RANGE PLANS (1982-86) TO INVEST IN ROBOTICS, CURRENT EXPERIENCE WITH ROBOTICS, NEW APPLICATIONS AND PREFERENCES FOR NEW PRODUCTS
- ONE THIRD OF FIRMS ALREADY USE ROBOTS
- COMPUTERIZED ANALYSIS ALLOWED COMPREHENSIVE STUDY OF TRENDS
- CAVEATS - INHERENT BIAS - RESPONDEES HAD A KNOWLEDGE AND INTEREST IN ROBOTS
- SURVEY DATA - EARLY 1982 - SOME CAPITAL SPENDING PLANS MAY HAVE BEEN DEFERRED

ROBOT USERS - VRS. NON-USERS - DIFFERENCES

	(1/3) ROBOT USERS	(2/3) NON-USERS
AVERAGE SALES (CO.)	$720 MILLION	$270 MILLION
SIZE OF DIVISION	470 PERSONS	133 PERSONS
AVERAGE 1982 INVESTMENT	$500 THOUSAND	$130 THOUSAND
ANTICIPATED ANNUAL INCREASE OF INVESTMENT	21%	N/A
BRAND PREFERENCE	42%	26%
UPPER MANAGEMENT RESISTANCE	15%	28%
IN-HOUSE FORMAL ROBOT PROGRAM	67%	21%

PRIORITIZED REASONS FOR ROBOT PURCHASES*

REASON	PERCENTAGE
REDUCE LABOR COSTS	27
INCREASE PRODUCTIVITY	25
IMPROVE QUALITY	18
REDUCE SCRAP	8
MEET COMPETITION	7
REDUCE INJURY	6
COUNTER LABOR PROBLEMS	5
SATISFY OSHA REGS.	3
OTHER	1
TOTAL	100

*INCLUDES ONLY THOSE FIRMS THAT HAVE PU[illegible]HASED ROBOTS

WORK PROCESS OF INDUSTRIAL ROBOTS - CURRENT VS. PROJECTED

TASKS	CURRENT	PROJECTED
MATERIAL HANDLING	15.1	21.3
MACHINE TOOL LOADING	10.0	10.2
ASSEMBLY	10.0	10.2
PRESS LOADING	8.5	7.9
PAINTING	7.6	7.5
PALLETIZING	7.5	7.6
INSPECTION	6.0	6.6
CARTON LOADING	5.7	5.7
MIG WELDING	6.6	7.2
SPOT WELDING	4.8	5.3
INJECTION MOLDING	4.0	1.7
DIE CASTING	3.5	1.0
ABRASIVE BLASTING	2.2	1.3
GLASS HANDLING	2.2	1.0
FORGING	2.1	1.0
INVESTMENT CASTING	1.0	0
VACUUM FORMING	1.0	0.5
COMPRESSION MOLDING	1.0	0.6
OTHER (DRILLING, ROUTING, TORCH CUTTING)	2.7	3.7
TOTAL**	100.5	100.3

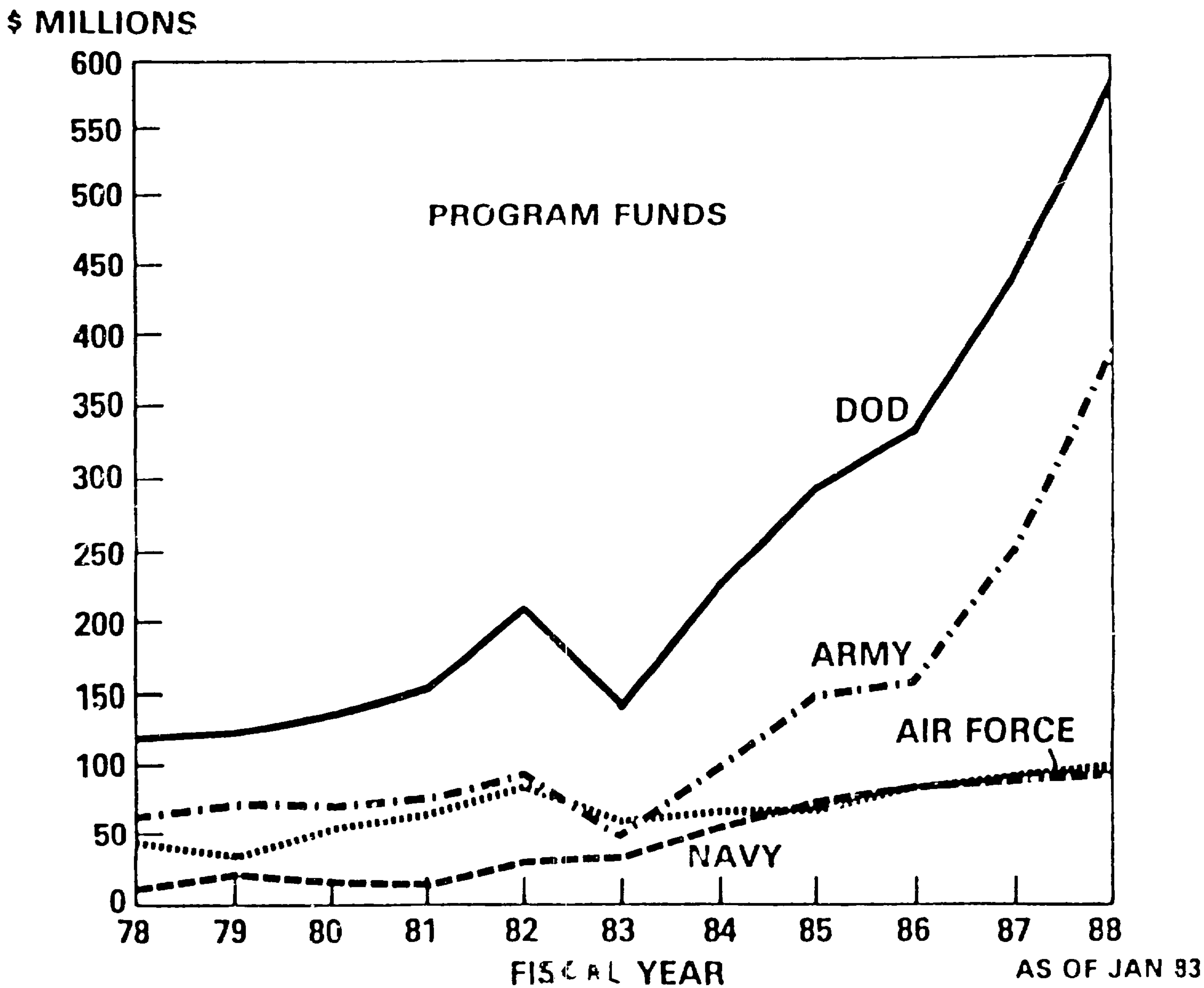
*SURVEY OF 500 U.S. INDUSTRIAL FIRMS. JANUARY 1982

**VALUES OF TOTALS OVER 100 DUE TO ROUNDING ERROR

DOD ACTIONS TO STIMULATE USE OF ROBOTS

- MANUFACTURING TECHNOLOGY PROGRAM
- TECH-MOD ARRANGEMENT
- LOGISTIC INITIATIVES - DEPSEC MAY 83
- RD & IRD FUNDING
- BATTLEFIELD ROBOTICS

DEPARTMENT OF DEFENSE
MANUFACTURING TECHNOLOGY PROGRAM

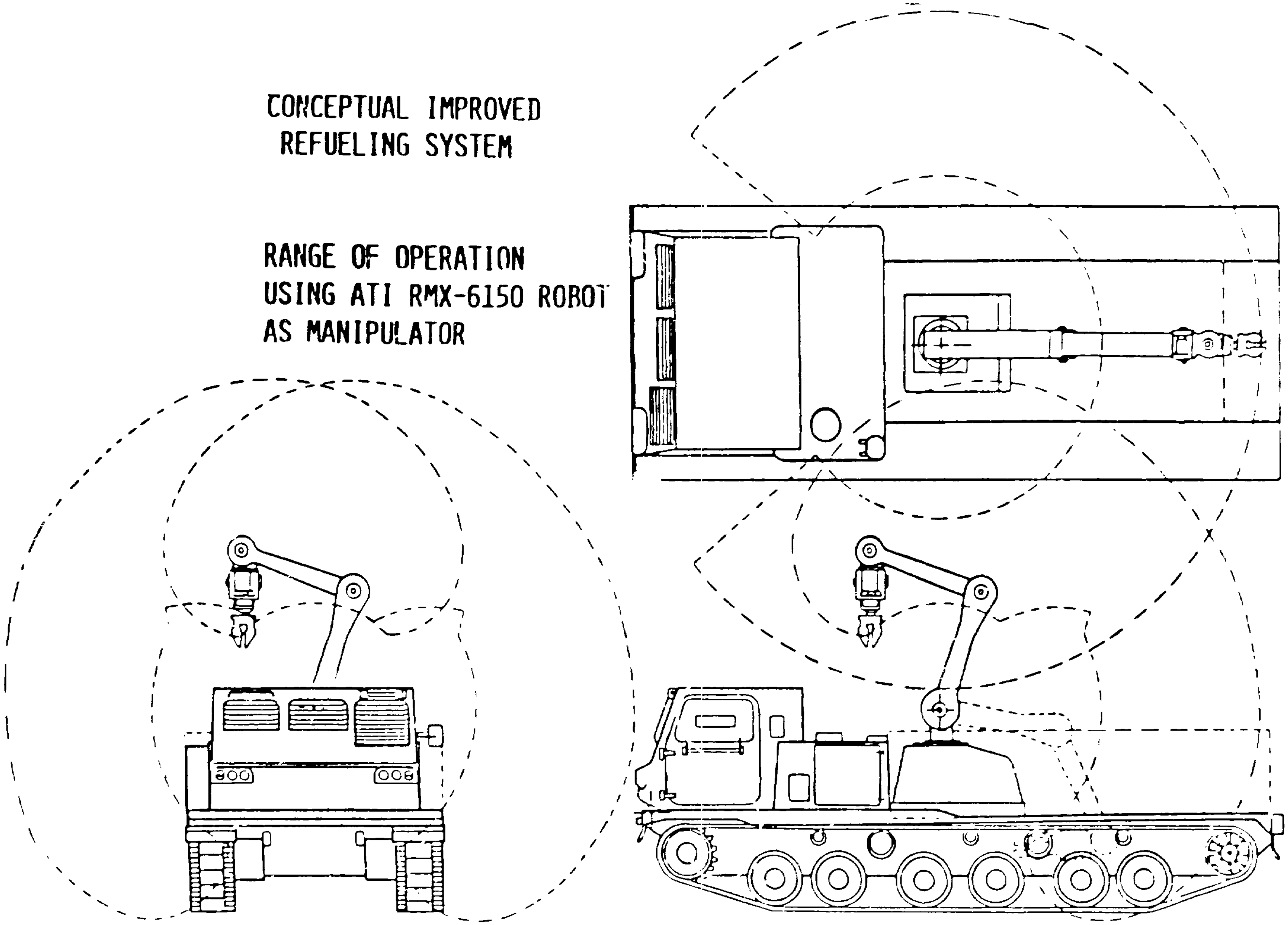


DOD LOGISTICS R&D PLAN

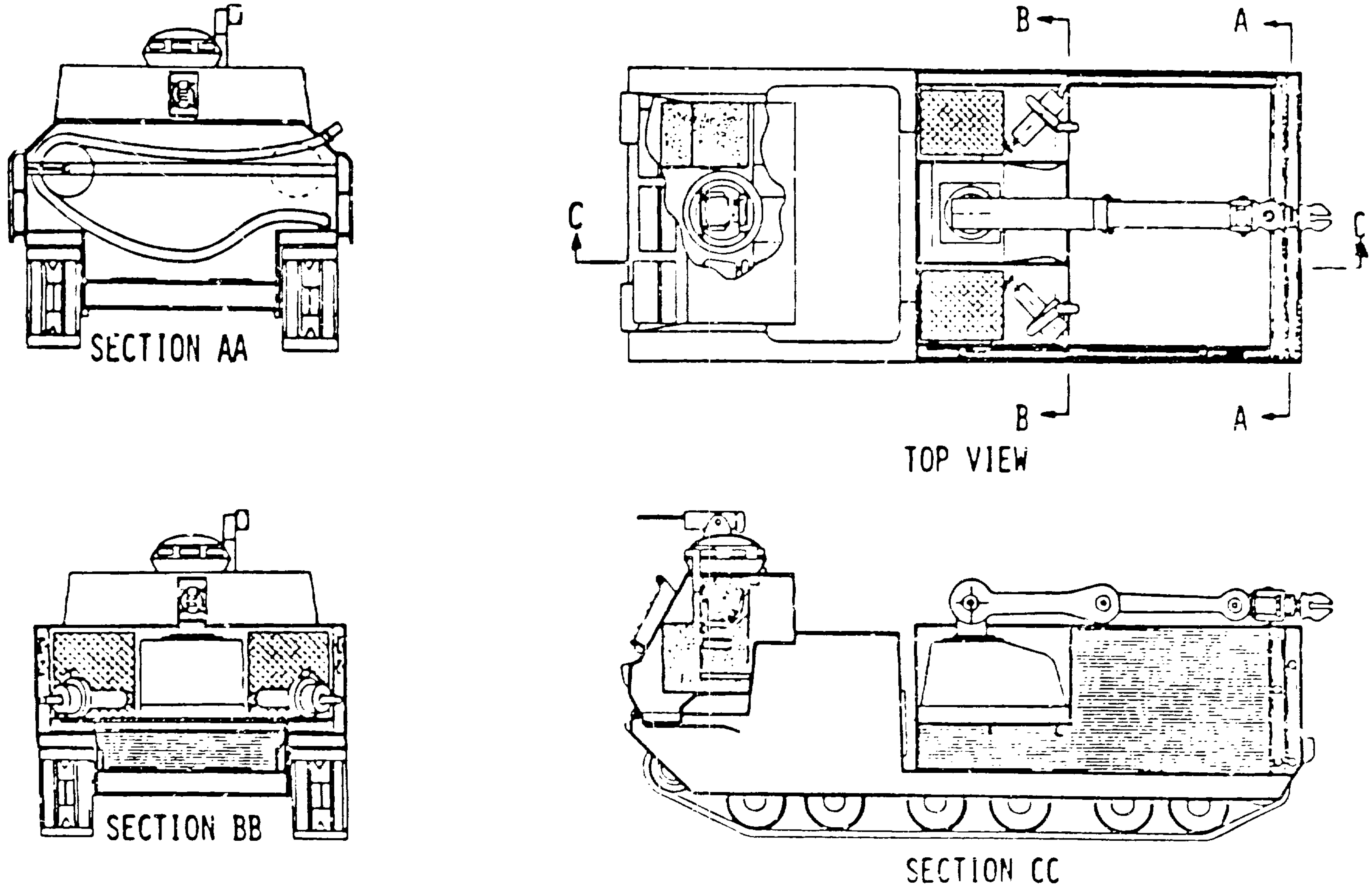
1. RELIABLITY TECHNOLOGY
2. MAINTAINABILITY TECHNOLOGY
3. DIAGNOSTICS TECHNOLOGY
4. AUTOMATIC TEST EQUIPMENT
5. LOGISTICS TRAINING AND SIMULATOR SYSTEMS
6. TECH DATA MANAGEMENT
7. MAINTENANCE AND OVERHAUL AIDS
8. METROLOGY FOR FIELDED WEAPON SYSTEMS
9. WEAPON SUPPORT MANAGEMENT, REPORTING AND ANALYSIS SYSTEMS
10. AUTOMATED SPARE PARTS MANUFACTURING/REPAIR
11. MATERIAL TRANSPORTATION, HANDLING AND DISTRIBUTION SYSTEMS
12. FUELS AND MUNITIONS TECHNOLOGY
13. LOGISTICS FACILITIES
14. LOGISTICS COMMUNICATION, INFORMATION AND MANAGEMENT SYSTEMS

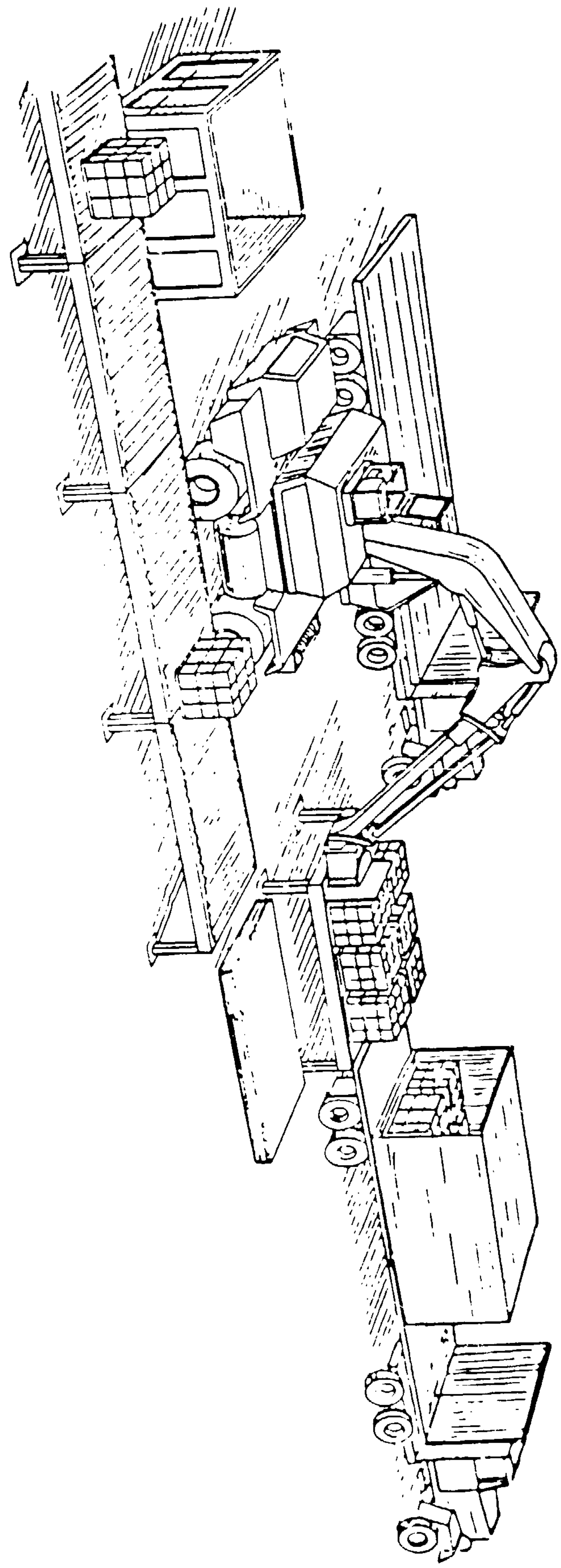
CONCEPTUAL IMPROVED
REFUELING SYSTEM

RANGE OF OPERATION
USING ATI RMX-6150 ROBOT
AS MANIPULATOR

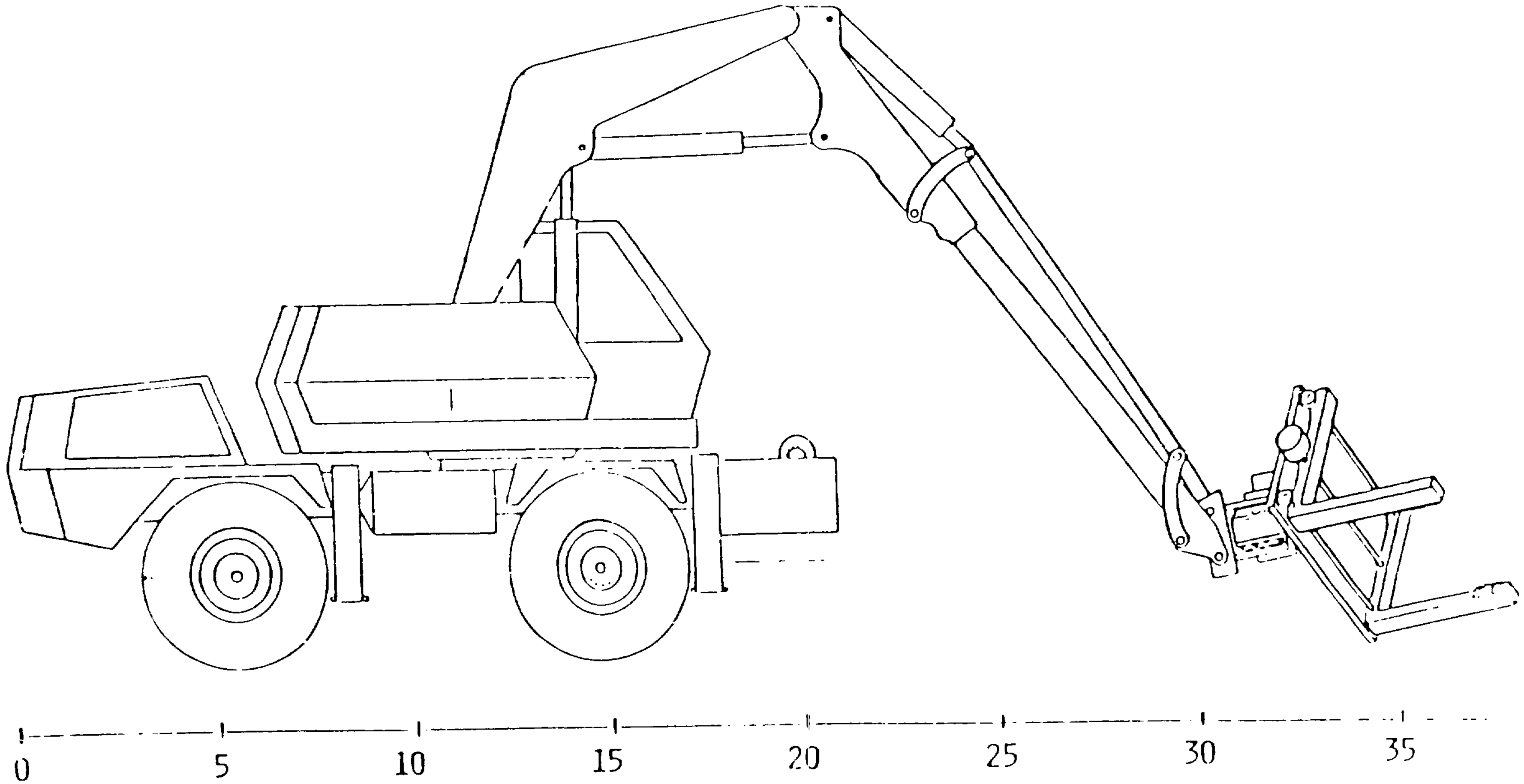


CONCEPTUAL IMPROVED REFUELING SYSTEM

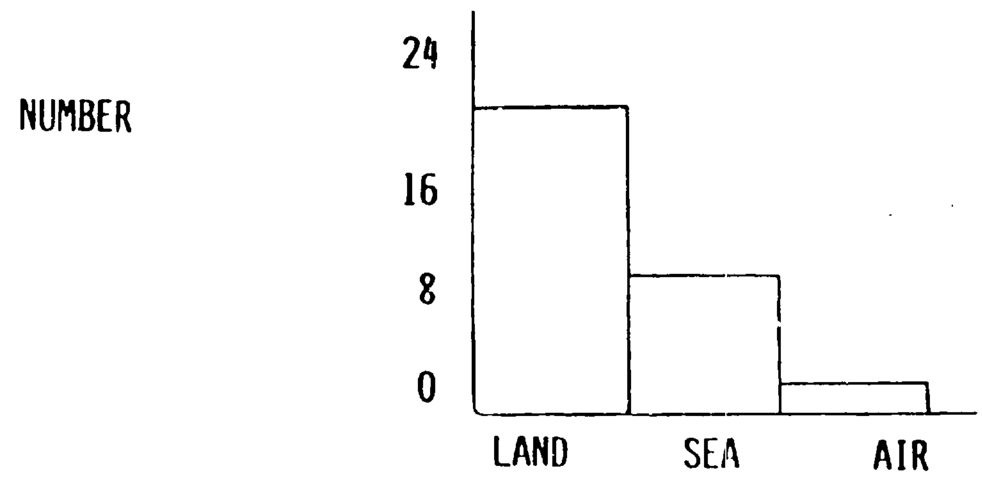




ROBOTIC PALLET LOADER - DEMONSTRATOR

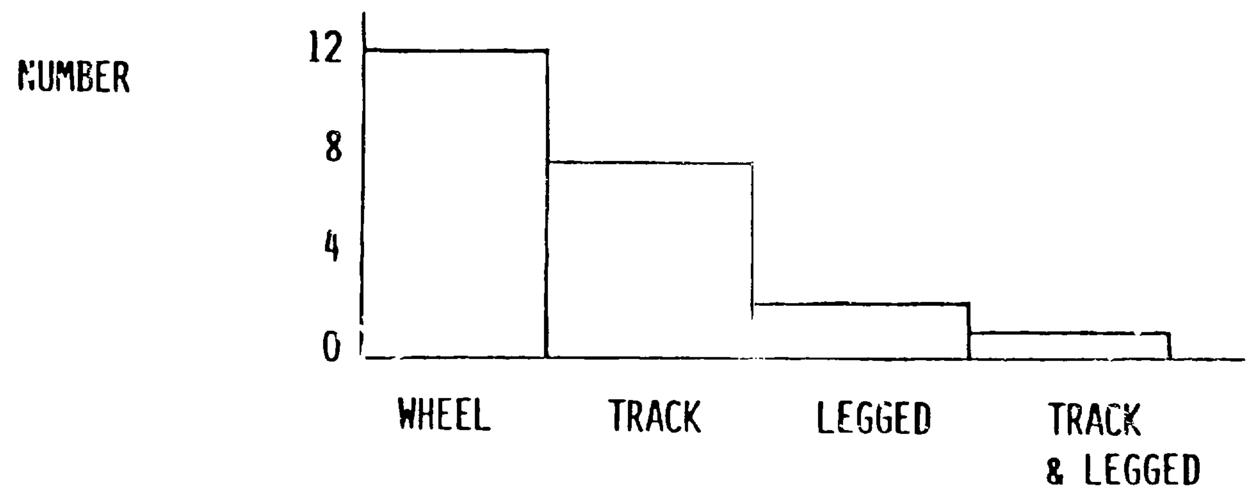


ROBOT VEHICLES - BASIC MEDIA OF OPERATION*



*36 VEHICLES TOTAL REVIEWED AS OF 9/83

ROBOT LAND VEHICLES - BASIC TRANSPORTATION METHOD*



*22 LAND VEHICLES REVIEWED AS OF 9/83

PRINCIPAL USES OF LAND ROBOT VEHICLES*

INCREASING	EXPLORATION	32%
	RECONNAISSANCE	23%
DIFFICULTY	SECURITY	18%
	PLANT MAINTENANCE	12%
OF	ORDNANCE DISPOSAL	10%
	MINING	5%
TASK	MANUFACTURE	5%
	TOTAL	100%

*22 LAND VEHICLES REVIEWED

SPECIAL REVIEW OF JAPANESE MOBILE ROBOTS

- MITI-SPONSORED RESEARCH HAS PRODUCED SEVERAL INTERESTING DEVICES
  - -- DRIVERLESS CAR
  - -- MEL DOG
  - -- SNAKE
  - -- WALKING MACHINE
  - -- WHEELED MAZE SOLVING ROBOT
- JAPANESE INDUSTRY HAS IDENTIFIED ABOUT 250 APPLICATIONS--SOME ARE IN IN USE ALREADY
  - -- WINDOW WASHING
  - -- FIRE FIGHTING
  - -- UNDERSEA WALKING MACHINE
  - -- REMOTELY OPERATED BULLDOZER
  - -- HOSPITAL ORDERLY
- ESPECIALLY ATTRACTIVE NEW APPLICATIONS POINTED OUT IN JAPANESE LITERATURE
  - -- POWER LINE MANIPULATION
  - -- CONSTRUCTION OF BUILDINGS
  - -- AGRICULTURE
  - -- SHIPBUILDING

COMBINED MARKET ASSESSMENT

- NUMBER OF COMPANIES CURRENTLY ACTIVE -- 50
- CUMULATIVE UNIT SALES -- 150
- ANNUAL SALES VOLUME -- $1-2M/YEAR - EQUIPMENT
- TYPICAL UNIT COST - $250K
- RESEARCH AND DEVELOPMENT - $3-5M/YEAR
- FRACTION OF COMPANIES PRIMARILY IN RESEARCH ARENA -- 15%
- PRINCIPAL RESEARCH EFFORTS - COMMERCIAL
  - -- WESTINGHOUSE
  - -- GCA
  - -- MBA/TRACOR
  - -- ODETICS
  - -- SUMIMOTO
  - -- KOMATSU
  - -- HUGHES AIRCRAFT

COMBINED MARKET ASSESSMENT (CONTINUED)

- PRINCIPAL RESEARCH EFFORTS - NON-COMMERCIAL
  - -- OHIO STATE
  - -- UNIVERSITY OF MOSCOW
  - -- TOKYO INSTITUTE OF TECHNOLOGY
  - -- CARNEGIE MELLON
  - -- UNIVERSITY OF MARYLAND
- PRINCIPAL GOVERNMENT SPONSORS OF RESEARCH - LAND VEHICLES
  - -- DARPA
  - -- USSR
  - -- MITI
  - -- NVL/USA FT. BELVOIR
  - -- MERADCOM USA FT. BELVOIR (HISTORICAL)
  - -- NOSC/SAN DIEGO AND HAWAII (ALSO PERFORMING RESEARCH)

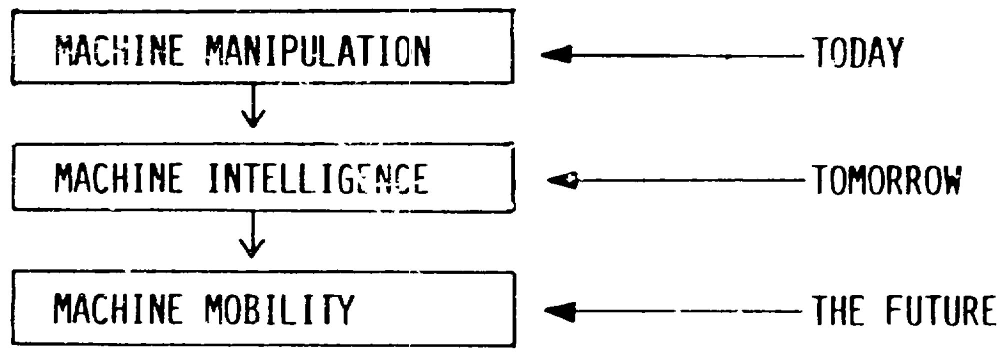
MILITARY MOBILE ROBOT APPLICATIONS BY FUNCTIONAL AREA

TACTICAL WARFARE	LOGISTICS	MANUFACTURING	OTHER
RECONNAISSANCE	AMMUNITIONS HANDLING, TRANSPORT	MOBILE ARC WELDING	INTELLIGENCE GATHERING
COUNTERMINE SYSTEMS DETECTION, REMOVAL	FUEL HANDLING, TRANSPORT	LASER PAINT REMOVAL	DECONTAMINATION
SURVEILLANCE	REMOTE MAINTENANCE	TRANSPORT SYSTEMS	PLANT MAINTENANCE
DECOYS/DISTRACTION/DECEPTION	PHYSICAL SECURITY	LOADING/UNLOADING	FIRE FIGHTING
PAYLOAD DELIVERY	WATER SUPPLY LOCATION, DISTRIBUTION		RESCUE
FORTIFICATION/ENTRENCHMENT	WASTE DISPOSAL		UNDERWATER SENSING/ SURVEILLANCE
BARBED WIRE EMPLACEMENT	SHIP TO SHORE TRANSPORT		UNDERWATER CUTTING, MAINTENANCE
BARRIER BREACHING	TRUCK LOADING/UNLOADING		TUNNEL DETECTION
BRIDGING	ROAD CLEARING/SNOWPLOWS		
MINE HANDLING/PLACEMENT	CONTAINER HANDLING		
TARGET CLASSIFICATION/ LOCATION	SHIP LOADING/UNLOADING		
BATTLEFIELD RESCUE	CONSTRUCTION SUPPORT		
SENTRY	MECHANICAL HANDLING EQUIPMENT		
REMOTE RADIO JAMMING			
REMOTE SENSORS			
AMMUNITION LOADING			

MATRIX OF FUNCTIONAL AREAS FOR LAND MOBILE ROBOTS

	USA	USN	USAF	OTHER
TACTICAL WARFARE	X			
LOGISTICS	X	X	X	X
MANUFACTURING	X	X	X	X
OTHER	X	X	X	X

CONCLUSION


MACHINE MANIPULATION
MACHINE INTELLIGENCE
MACHINE MOBILITY
TODAY
TOMORROW
THE FUTURE

AIRCRAFT REPAIR WITHIN THE AIR FORCE LOGISTICS COMMAND

-SACRAMENTO AIR LOGISTICS CENTER, AIRCRAFT DIVISION-
SM-ALC/MAB

BY: GORDON LANGENBECK

The Air Force Logistics Command organically manages and repairs aircraft and aircraft components at each of the five Air Logistics Centers (ALCs). Aircraft systems and aircraft components are managed by the Directorates of Material Management at the five ALCs.

Aircraft repair is performed by the Directorates of Maintenance. Component repair is done by Technology Repair Center concept where each Directorate of Maintenance specializes in certain types of repair. For example Sacramento ALC both manages and repairs the F-111 airframe while Ogden Air Logistics Center manages and repairs landing gear components for all Air Force aircraft.

AFLC STRUCTURE
HEADQUARTERS: WRIGHT-PATTERSON
DAYTON, OHIO

SACRAMENTO AIR LOGISTICS CENTER
SAN ANTONIO AIR LOGISTICS CENTER
OKLAHOMA CITY AIR LOGISTICS CENTER
OGDEN AIR LOGISTICS CENTER
WARNER ROBINS AIR LOGISTICS CENTER
AIR FORCE GUIDANCE & METROLOGY CENTER
MILITARY AIRCRAFT STORAGE & DISPOSAL CENTER

AIRCRAFT MANAGEMENT

DIRECTORATES OF MATERIAL MANAGEMENT
SYSTEM MANGEMENT
ITEM MANAGEMENT

AIRCRAFT REPAIR

DIRECTORATES OF MAINTENANCE

SPECIALIZED REPAIR ACTIVITIES
TECHNOLOGY REPAIR CENTERS (TRC's)

EXAMPLES OF TRC's

LANDING GEAR - OO-ALC
FLIGHT CONTROL INSTRUMENTS - SM-ALC
AUTOMATIC FLIGHT CONTROL SYSTEMS - OC-ALC
AIRBORNE ELECTRONICS - WR-ALC
SUPPORT EQUIPMENT - SA-ALC

ENGINES - SA-ALC & OC-ALC

WORLD WIDE TDY RESPONSIBILITY ON PRIME AIRCRAFT

F-111 OVERVIEW

SYSTEM MANAGEMENT:	SM-ALC
ITEM MANAGEMENT:	ALL 5 ALCs IN MMI DEFENSE LOGISTICS AGENCY, I.E., S91, S9E
SPECIALIZED REPAIR ACTIVITY:	SM-ALC & BAE
ENGINES:	OC-ALC

TECHNOLOGY REPAIR CENTERS

AIRFRAME COMPONENTS	SM-ALC
LANDING GEAR	OO-ALC
AIRBORNE ELECTRONICS	WR-ALC
FLIGHT CONTROL INSTRUMENTS	SM-ALC
AUTOMATIC FLIGHT CONTROL SYSTEM	OC-ALC

TYPICAL DEPOT REPAIR PROCESS F-111

INCOMING FLIGHT PREP
INCOMING FUEL
DEPAINT (IF REQ'D)
MODIFICATION CENTER
FINAL SELL
PAINT (IF REQ'D)
OUTGOING FUEL
OUTGOING FLIGHT PREP
FUNCTIONAL CHECK FLIGHT
DELIVERY

TAKES APPROXIMATELY 10 - 14,000 HRS AND 60 TO 75 WORK DAYS

SIZE OF AFLC AIRCRAFT REPAIR

OC-ALC	1908	PERSONAL EQUIVALENTS (PE's)
OO-ALC	2404	PERSONAL EQUIVALENTS (PE's)
SA-ALC	1428	PERSONAL EQUIVALENTS (PE's)
SM-ALC	1696	PERSONAL EQUIVALENTS (PE's)
WR-ALC	2232	PERSONAL EQUIVALENTS (PE's)

SIZE OF SM-ALC AIRCRAFT WORK LOADS

A-10	457	PERSONAL EQUIVALENTS (PE's)
FB-111	165	PERSONAL EQUIVALENTS (PE's)
F-111	653	PERSONAL EQUIVALENTS (PE's)
F-4D	133	PERSONAL EQUIVALENTS (PE's)
F-5	2	PERSONAL EQUIVALENTS (PE's)
F-106	192	PERSONAL EQUIVALENTS (PE's)

T-39	87	PERSONAL EQUIVALENTS (PE's)
A-37	7	PERSONAL EQUIVALENTS (PE's)
TOTAL	1696	PERSONAL EQUIVALENTS (PE's)

AIR FORCE ENGINE REPAIR

-OKLAHOMA CITY AIR LOGISTICS CENTER, PROPULSION DIVISION- OC-ALC/MAE

BY: MAURICE LEBLANC

My purpose today is to acquaint you with jet engine overhaul facilities and process at the Oklahoma City Air Logistics Center, which produces approximately 200 aircraft, 1200 engine and 300,000 component items each year.

Organizationally we utilize three product divisions within the Directorate to accomplish this work. Because of the time constraint I will only discuss the basic engine overhaul processes accomplished by the Propulsion Division. External items on the engine, i.e., accessories and tubing are processed by the Accessories Division and will not be included in this presentation.

The Air Force Logistics Command manages a jet engine inventory of approximately 60,000 engines. By contrast the Free Worlds largest commercial carrier manages about 1,600 engines. Engine overhaul is accomplished at two Air Logistics Centers, San Antonio and Oklahoma City. Today I will be describing the Oklahoma City Air Logistics Center operations, but you may want to keep in mind that a similar capability exists at San Antonio.

The basic engine work load at Oklahoma City is accomplished in building 3001 and three other out-buildings which includes two test cells. Totally we utilize in excess of 1 million square feet of industrial floor space.

Currently OC-ALC overhauls 5 different jet engines of which the J79 is the latest addition to our work requirements (Photo #1). The J79 engine is used on the F4 aircraft. The F4 Phantom Jet is still a very important part of the overall defense posture of the USA.

The J57 engine is one of our older work requirements at OC-ALC (Photo #2). 8 J57 engines are used on the B52 Bomber and 4 are used on the KC135 Refueler Aircraft.

The TF33 engine (Photo #3) is used on numerous aircraft of which include the C141, B52 and F3A aircraft. Each of these aircraft require 4 TF33 engines.

The TF30 is used on the F111 Aircraft, (Photo #4). The F111 is a swing aircraft that travels better than twice the speed of sound and is a very important part of our nations defense.

The TF41 Engine is the power pack for the A7 Fighter (Photo #5).

Looking ahead to the future work load for the Directorate of Maintenance Propulsion Division include:

The F101 Engine (Photo #6) is a very advanced state-of-the-art jet engine and strengthens our skill capabilities. This engine will power the B1 Bomber. Production is to begin in July 1985. The B1 Bomber is our nations most advanced Bomber with the most sophisticated avionics of and Bomber in the Air Force inventory.

Also scheduled for overhaul at OC-ALC is the F108 Engine (Photo #7). This engine will replace the J57 Engine for use on tanker models of the KC135 Aircraft. This engine will provide improved environmental consideration and fuel economy. Production to begin November 1986. The KC135 Aircraft provides in-fight refueling for prime national defense aircraft.

The F110 Engine (Photo #8) is scheduled for production beginning March 1986 and will power some of the F-16 Fighters. The F-16 is one of the latest fighters in the Air Force inventory.

Engines are received at OC-ALC in either a fly-away trailer or in an engine container. The engine is inspected on receipt to determine the extent of overhaul required. The records are checked to insure latest mods have been accomplished. The maintenance of the engine begins in Bldg 3001.

The engine is disassembled IAW tech orders and project directives. Components are disassembled to the level that required cleaning, inspection and repairs can be accomplished. The engine is then moved into the appropriate disassembly line for work to be accomplished.

The first stop is in the elevator where major components are separated. The compressor is unstacked. Each stage of the rotor is checked for FOD damage as the rotor is disassembled. The blades are then manually removed from the disk. Some engines secure the blade with tab locks which require a tab bending machine be used prior to removal of blade disk.

As the engine is disassembled, the parts are loaded in cleaning baskets IAW i structions indicating methods of cleaning to be used to adequately clean the parts to the extent necessary for required inspection to be accomplished.

The chemical cleaning area consists of 6 line and 65 process tanks. 20 chemical processes are used here consisting of 4 basic types of cleaning materials which are solvent cleaners, carbon and paint remover, alkaline cleaners and

acids. A central computer controls process sequence parts line which consists of 8 process tanks and 6 chemical processes. A special line is used for small or critical parts which require special handling. At a computers direction and for a pre-determined amount of time the baskets are lowered into the cleaning tanks.

Another method of cleaning is abrasive blasting. This is a process used for cleaning of material by forceful direction of abrasive grain. Abrasive blasting can be dry, or where the material is suspended in liquid.

Vibratory machines are used for cleaning blades and small parts. These machines are equipped with an eccentric weighted shaft attached to a bowl or tub. Many different sizes of blades and small parts are processed through our vibratory cleaning machines. The parts are then removed from the cleaner and sent to parts inspection.

We process approximately 250 items per engine through our overhaul shop for various stages of inspection and rework. We utilize 678 machines and booths for cleaning, inspection and repair. We also utilize 12 test cells, 45 balance machines and 30 elevators.

In our semi-automated (FPI) Fluorescent Penetrant Inspection manual load station parts are loaded onto the parts handlings fixture for processing through the FPI system. The micro-processor is programmed for correct process sequence. Parts processed through the semi-automated FPI system are automatically sprayed by the electrostatic wet developer application guns. Penetrant is also applied the same way.

Many methods of inspection are used to insure all defects or damages are identified. Fluorescent penetrant is one of the most widely used processes at Tinker. When using a black light the cracks are illuminized. Magnetic partial inspection is also used on many parts to determine cracks and defects. Visual inspection is performed to detect obvious defects and cracks. Magnifying glasses are often used. X-ray inspection is used to date circumferential weld inspection of an engine case. Blade airfoils are inspected using ultra-sonic for in-service defects.

Eddy current inspection of dovetail reveals a fatigue crack that occurs in this area during service. Tie rod holes are also inspected using eddy current method, the results are recorded on chart paper. Our Eddy Current II Inspection System is semi-automated. The computer provides part and inspection probe manipulation. Inspection results are automatically evaluated and recorded.

Roundness of bearing surfaces are measured using an Indi-Ron (Photo #9).

A VTL machine is used in a heavy machine shop. These machines are very accurate in removing metal. In depth machining on parts are accomplished in the heavy machine shop area.

We utilize numerical control (NC) machines for precision drilling and reaming of bolt hole circles and bores.

Various machining processes are implemented by different machines. Surfaces are machined using engine lathes such as Turbine Disk Snap. Inside dimensions are machined using a horizontal boring machine. Holes and slots are formed using an electrical discharge machine to burn away material. Extremely accurate diameters are ground on compressor disk on a grinding machine. Bearing journals and pump housing are ground on a jig borer in gearbox rework shop. Internal diameters with smooth surface finishes are successfully ground on an internal grinding machine.

During the rework cycle, parts are inspected for circular runout, concentricity and flatness. In combustion chamber rework area hand grinding, blending and butterfly polishing is accomplished. The J79 turbine nozzle rework is accomplished by using a high speed hand grinder. Electro-chemical grinding is used to restore turbine blades to original dimensions after weld repair. Extremely hard coatings are lapped on seal plate surfaces to a mirror finish. Flatness is held to within two light bands. Using dabber weld machine knife edge seals and selected snap diameters are successfully restored. Minimal distortion with major benefit from the dabber TIG units. A titanium fan inlet case weld is protected from contamination by surrounding it with an argon atmosphere. Very narrow heat affected zones, deep penetration and pinpoint accuracy are obtainable using electron beam welding.

Surfaces and diameter of engine items are prepared for plasma spray using grit blast and masking techniques. Plasma spray is applied to engine parts to restore surfaces and diameters to machinable dimensions. Plasma spray is applied using a semi-automated unit (Photo #10). The spray is also applied manually to areas that are inaccessible with other methods as in certain gearbox housings.

Masking material is applied to flange of a case during preparation for plating. Chrome, silver, nickel and cadium are plated on numerous engine parts in the plating facility. When masking and cleaning preparations are completed a case is lowered into a nickel plate tank. Corrosion preventive paints and anti-galling compounds are applied in the paint shop. SermeTel, a special corrosion preventive aluminum paint is used. Polyurthene paint is also used for corrosion prevention.

Our shops utilize vacuum furnaces with hydrogen particle pressure capabilities. Parts are stress relieved utilizing these furnaces. We also use conventional heat treat furnaces for parts that do not require protective atmosphere.

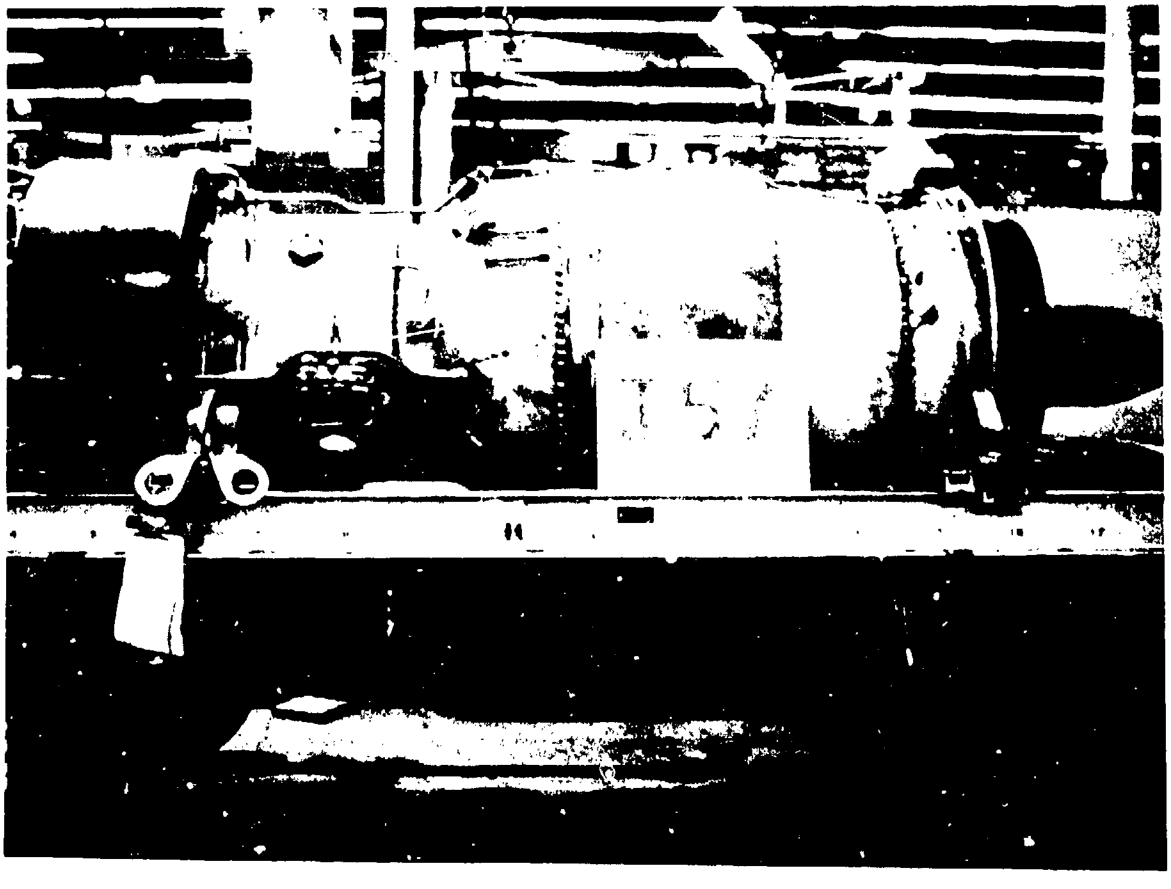
Parts are moved throughout the overhaul shop using automated power conveyor lines consisting of 3 miles of conveyor. Parts that have been completed are moved into serviceable stacker where parts are held until they are needed. The conveyor and stackers are controlled by computerized tracking system.

Blades are installed into the disk manually. The assembly of the engine is now in probes. After blading the disk, then each disk is static balanced on the J79 engine. The compressor rotor is stacked IAW the technical order. The high speed compressor rotor is then torqued. After the rotor has been stacked, it is then dynamic balanced prior to installation into an engine.

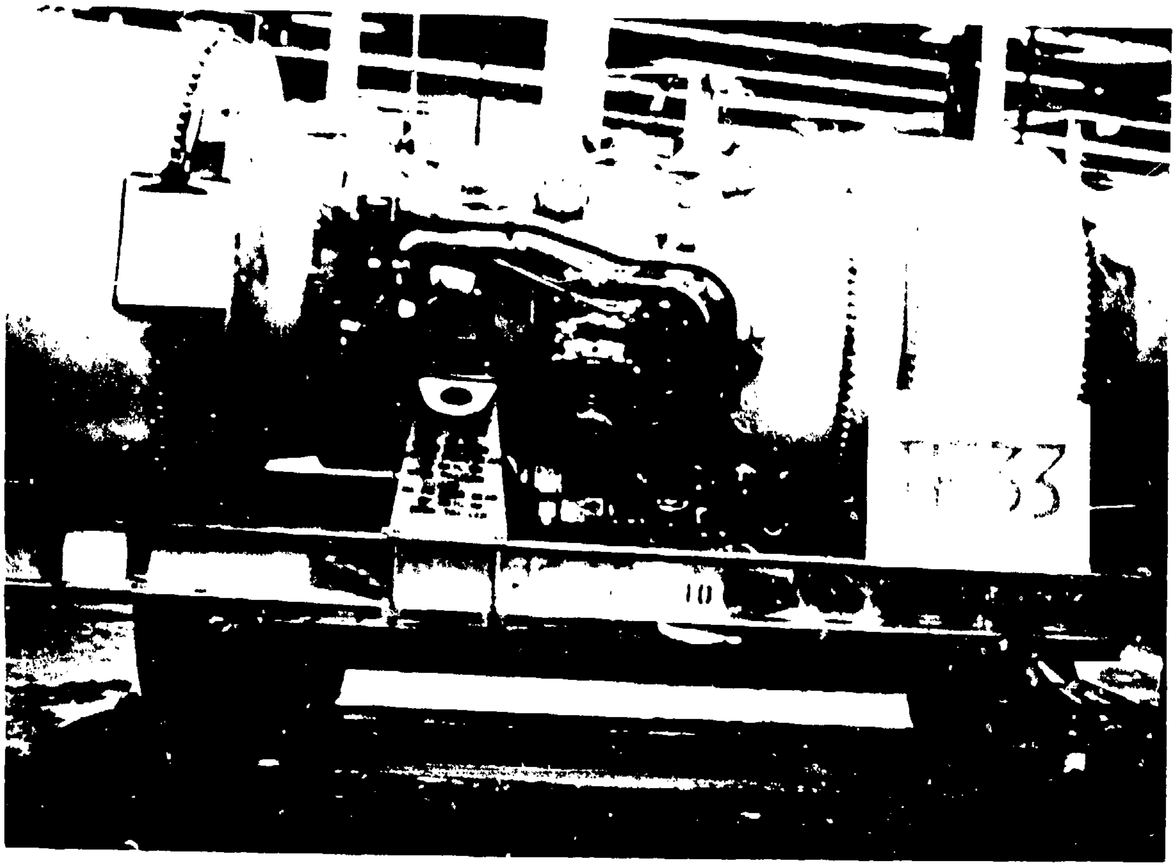
Major components and cases are then installed as the engine is stacked in vertical position. Tubing and accessories are added as the engine is plumbed.

Tinker AFB has one of the best test facilities in use. We have a closed loop computer controlled listing system operated in a real time made in which engine controls and test cell functions are fully automated. An engine is prepped prior to the test. Fuel and electrical harnesses are attached to engine prior to moving the engine into the test cell. The engine is then moved into the test cell and made ready for the test run. As the engine is run, operators monitor the engine. An engine vibration analysis is performed on all engines while the engine is being tested. After the engine has been accepted off test, it is given one more inspection. The main item looked for is cracks in frames, loose connections and oil leaks. The engines are then returned to users in Fly-away trailers and engine containers.

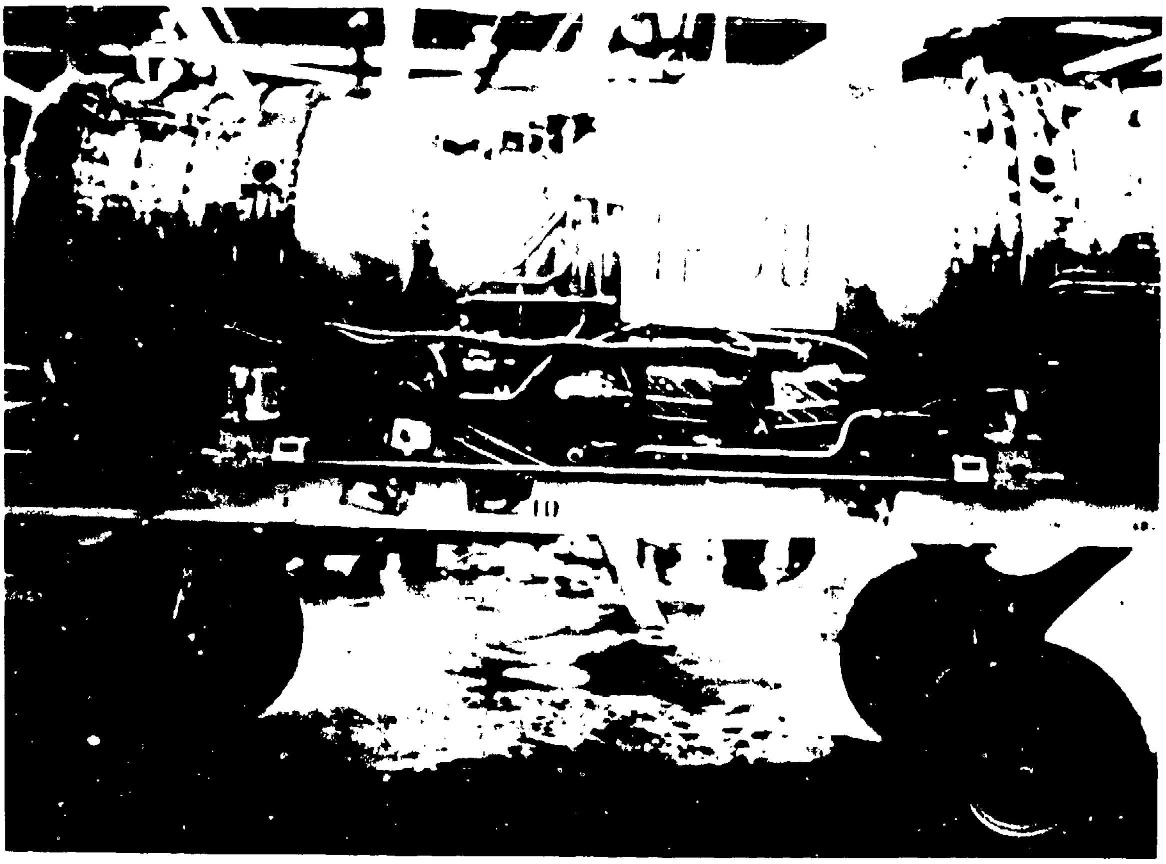
Photgraph #1



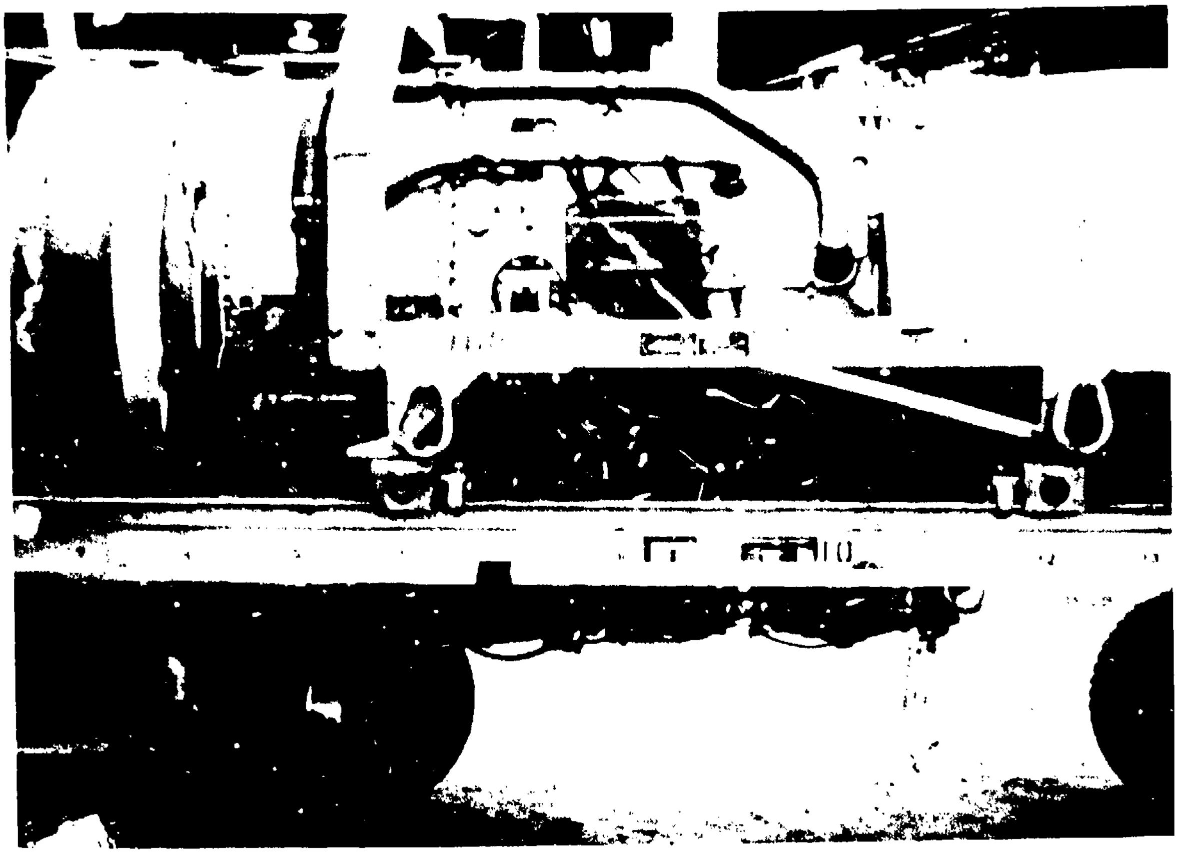
Photograph #2

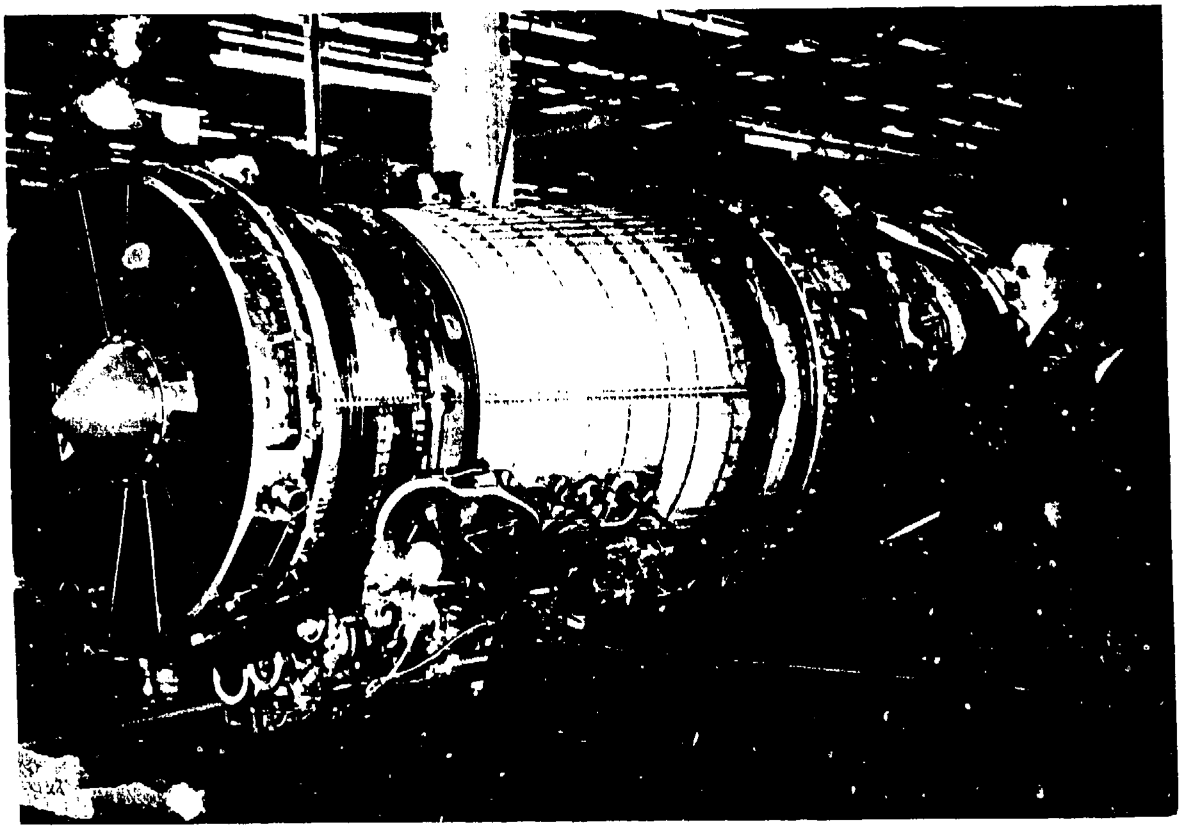


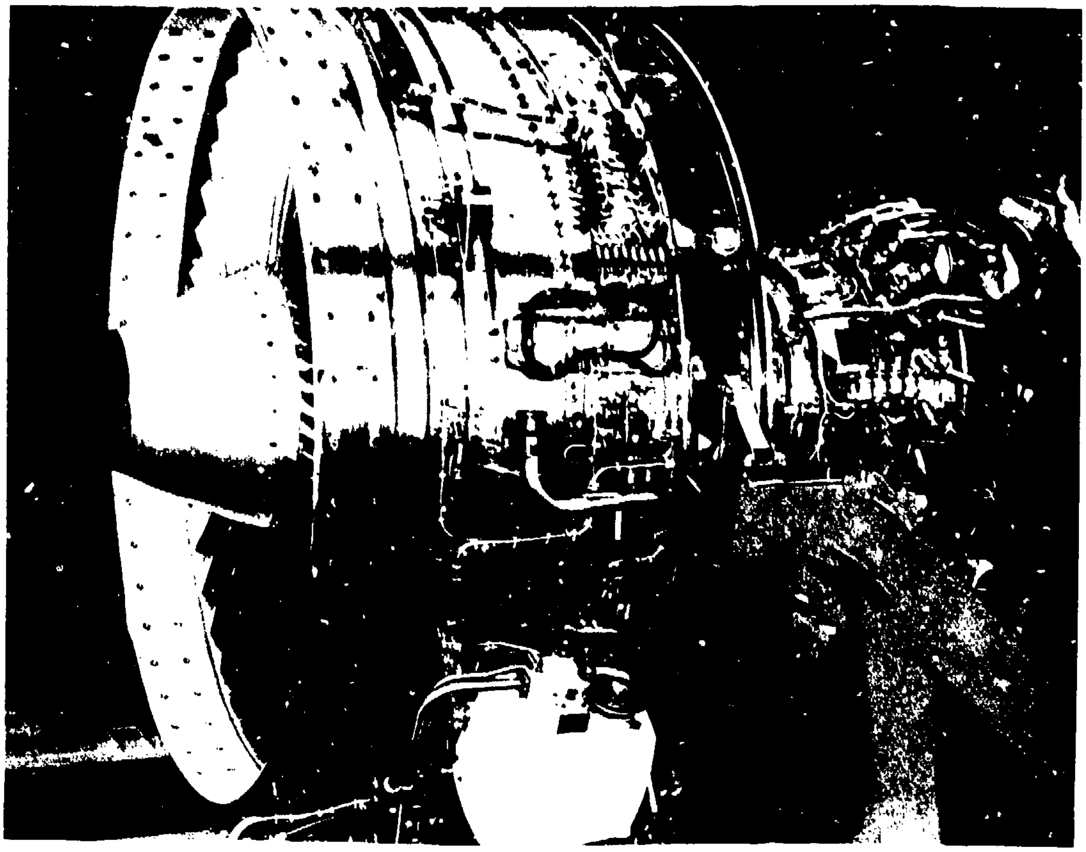
Photograph #3



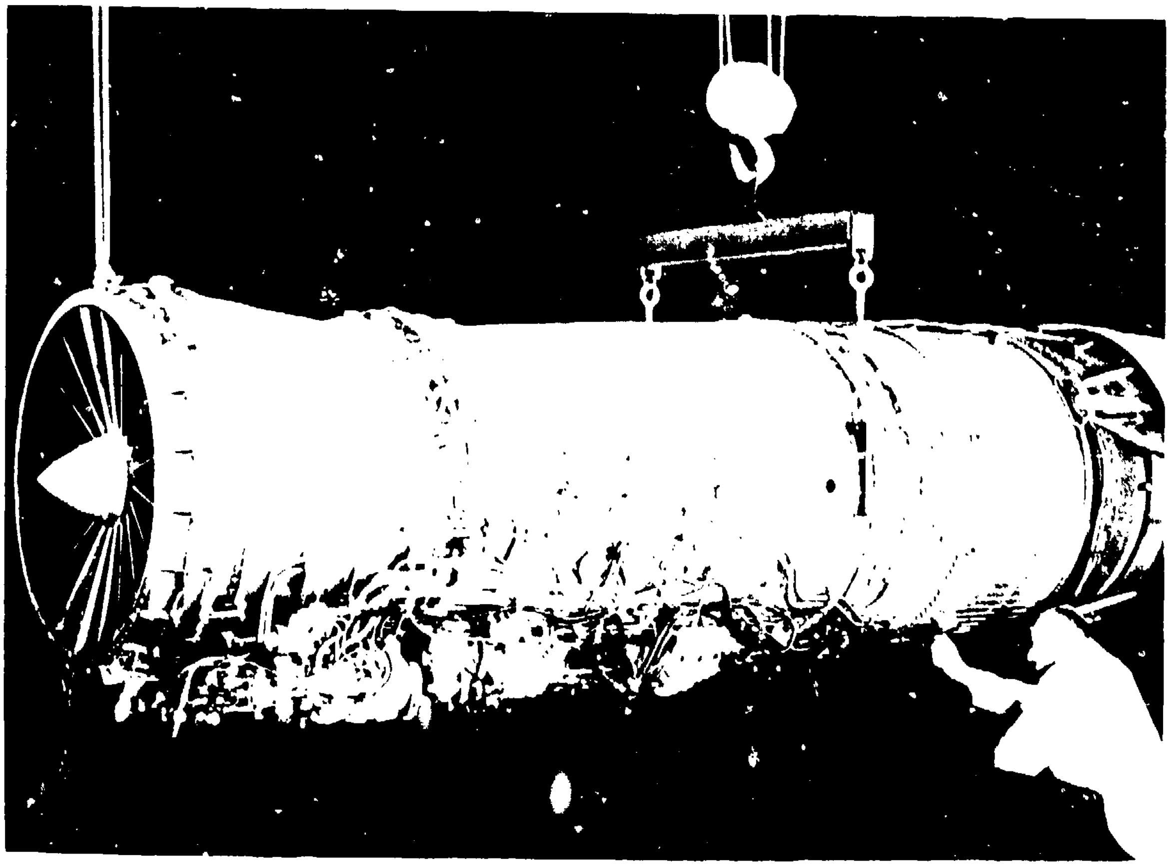
Photograph #4


Photograph #5

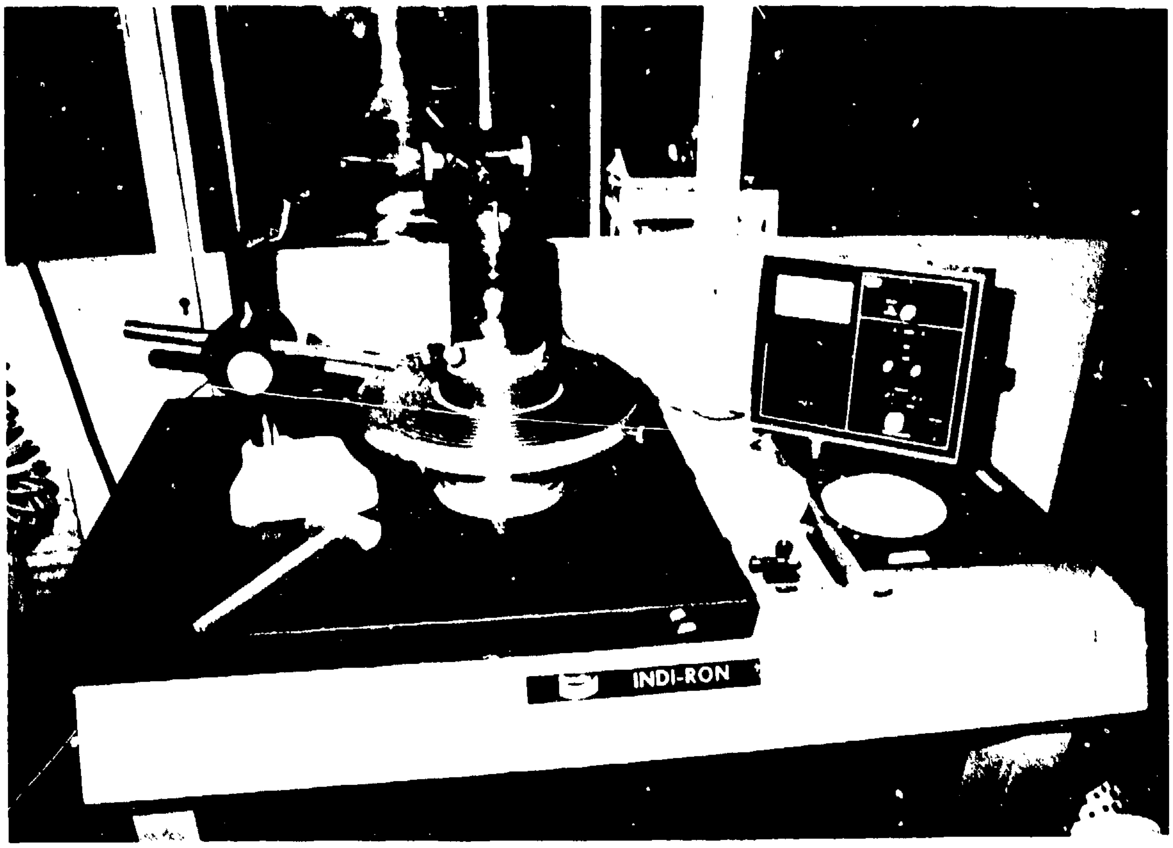

Photograph #6



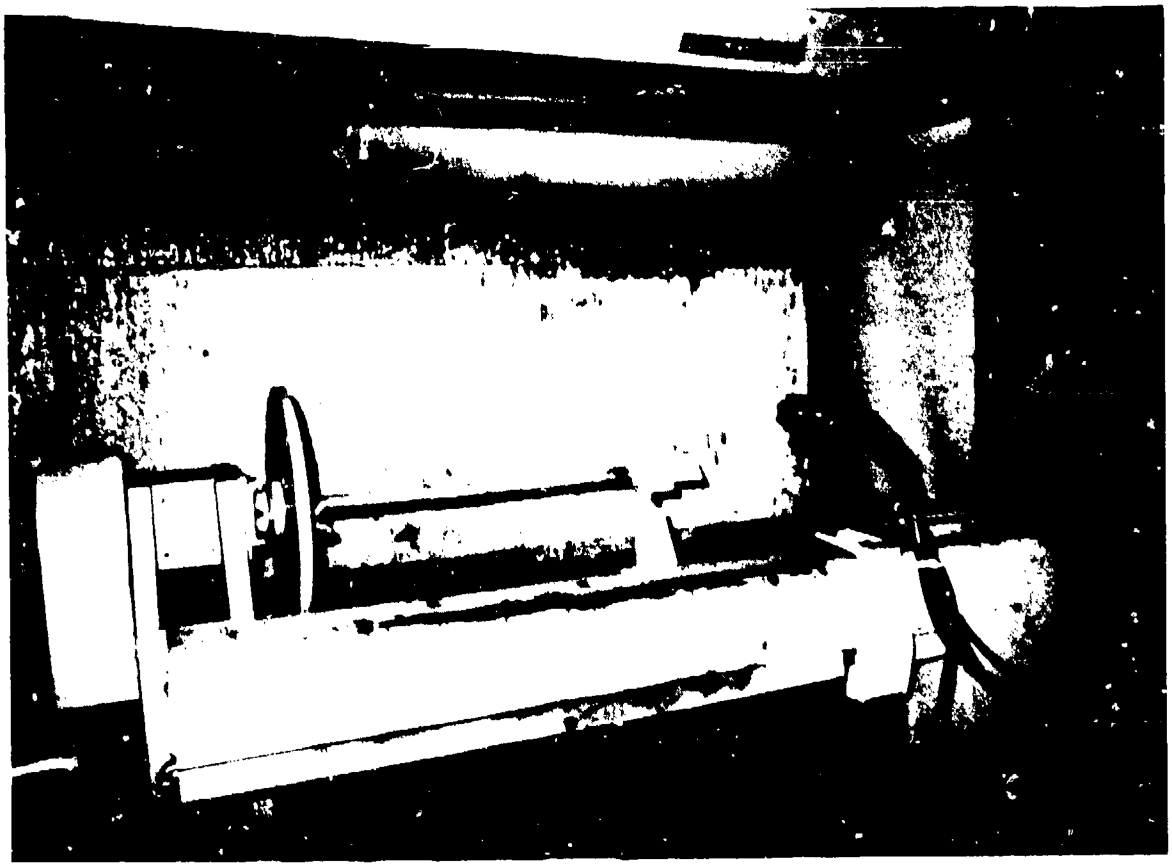
Photograph #7



Photograph #8



Photograph #9



Photograph #10

ELECTRONICS/AVIONICS DEPOTS IN THE UNITED STATES AIR FORCE

-WARNER ROBINS AIR LOGISTICS CENTER-
WR-ALC/MAIES

BY: BILL RAMSEY

1. Today's and yesterday's Airborne Electronic Systems and their myriad of components must be ready for use if the Air Force is to accomplish its mission of protecting and defending this nation's vital interest.

2. Maintaining ~~the~~ complex Airborne Electronic Systems has historically been accomplished at three repair levels.

3. The technical level of repair is dependent upon the complexity of the test equipment needed to isolate the malfunctions and then to functionally test a repaired item. No less important is the repair requirements involving facilities (heating, air conditioning, humidity, cleanrooms) and the special tools, fixtures and equipment with the skilled technicians and engineers whose knowledge utilize these resources.

4. The Electronic Depots at Ogden ALC, Utah; Sacramento ALC, California; San Antonio ALC, Texas and Warner Robins ALC, ~~Georgia~~ meet the need of repairing these items that cannot be repaired at field level.

5. To give you an insight as to how an Air Force Electronics Depot functions, I shall proceed to describe the facility at Warner Robins Air Logistics Center, which is typical of the others.

The primary Electronic Repair Area is 482,000 square feet, the Machine Shop Area is 5,182 square feet, the Training Area is 6,793 square feet and the Electronic Warehouse is 320,000 square feet. Total area in the complex is 814,265 square feet. Within this complex we are responsible for the repair of 330 major Avionic Systems comprised of 8,383 line items for which individual repair processes and procedures are available. During a typical fiscal year we process 210,000 items with an operating budget of $191 million dollars. Our work force of 2,400 people is composed of managers, engineering, technicians and other support groups.

6. The process of an item being repaired at Depot level is depicted in Chart 1.

a. First, the Item Manager makes a decision whether there will be an organic depot or if the item shall go to a contractor for depot repair. The item manager enters the appropriate codes into the Air Force Supply System.

b. When the item actually becomes operative, the using organization turns that asset into the Supply System. The Base Supply personnel ships the item to the designated depot.

c. The inoperative electronic components are staged at Depot Supply until the Item Manager triggers the Supply Computers that they need serviceable assets.

d. The Supply Computer merges their needs with other Management Computer Systems, and the Depot is tasked with repairing the inoperative assets.

e. The assets are then moved into the Depot and processing documentation is attached.

f. Next, the responsible production area inspects the unit for visual problems or necessary modifications.

g. The following step is to clean the item and to correct any visual problems.

h. An Electrical Test is accomplished on manual or automatic Depot Test Equipment in accordance with applicable technical orders. Fault isolation testing allows the technician to identify those components which have caused the malfunction.

i. The unit is returned to the worker on the Repair Bench for replacement of identified parts.

j. After repair, the item is again tested on the Depot Test Equipment for functional compliance.

k. The item is then painted, touched-up, and/or conformally coated as required.

l. Completed unit is tagged and ready for its final move to the Supply Warehouse.

7. This is a very simplistic look at the flow path of an electronic item in an Air Force Depot.

8. Next, I shall briefly attempt to let you see how the repair process is established.

9. Chart 2 is a graphic representation of the Planning and Scheduling function for the repair of an electronic item.

a. As shown on Chart 1, we again see that the Item Manager starts things moving by sending the appropriate request to the Depot Planner.

b. The Depot Planner is the key person in seeing that processes and procedures are available for the repair of electronic items.

c. The Planner acts as a chairperson of the Pre-Planning Team. Each member carries out the functions shown in horizontal blocks on Chart 2.

d. When all factors are satisfactorily ready, the Planner opens a control number in the Logistics Computer.

e. The Computer controls an operating system we call MISTR (Management of Items Subject to Repair).

f. The open control number triggers a work load product which projects the bi-weekly requirements for an extended period of time. These figures are negotiated and a forecast is projected.

g. Next, the bi-weekly computer products are generated which allow the Scheduler to actually bring assets and support parts into the Repair Shops.

10. The rest of the process is accomplished as was shown in first part of this Briefing.

11. The methods presented of processing electronic items through the various Repair Depots only address the Logistics. The actual hand on work operations involves many different job elements, such as the soldering of components, cleaning, conformal coating, probing and testing, movement from station to station, and painting. These operations for the most part are preformed in a random sequence since the repair accomplished is in direct relation to the equipment malfunction. The Air Force Electronic Depots are actively seeking methods and means to increase our productivity and lower our operating cost.

AVIONIC EQUIPMENT FLOW DIAGRAM

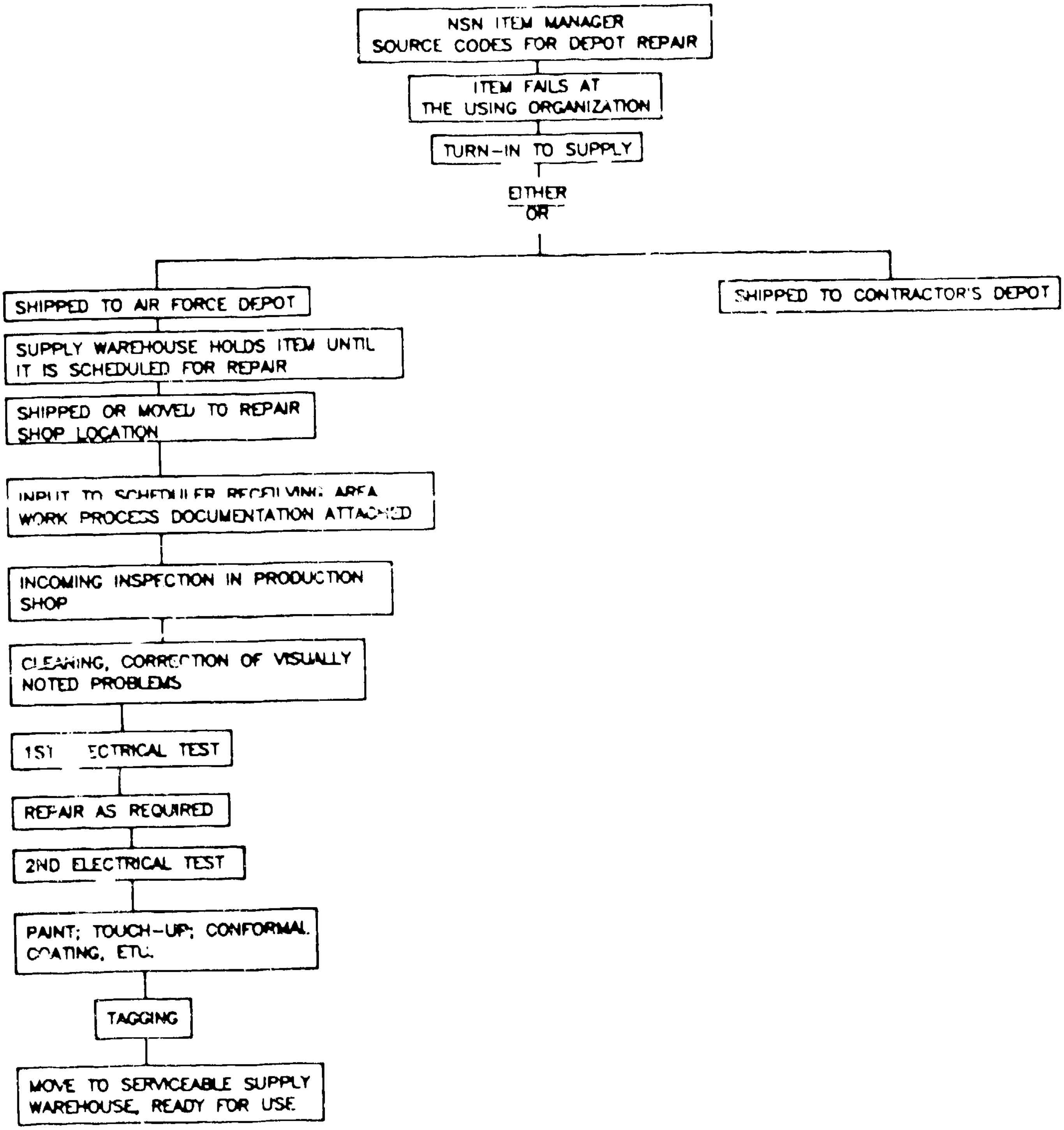


CHART I

AVIONICS EQUIPMENT REPAIR PROCESS
PLANNING AND SCHEDULING

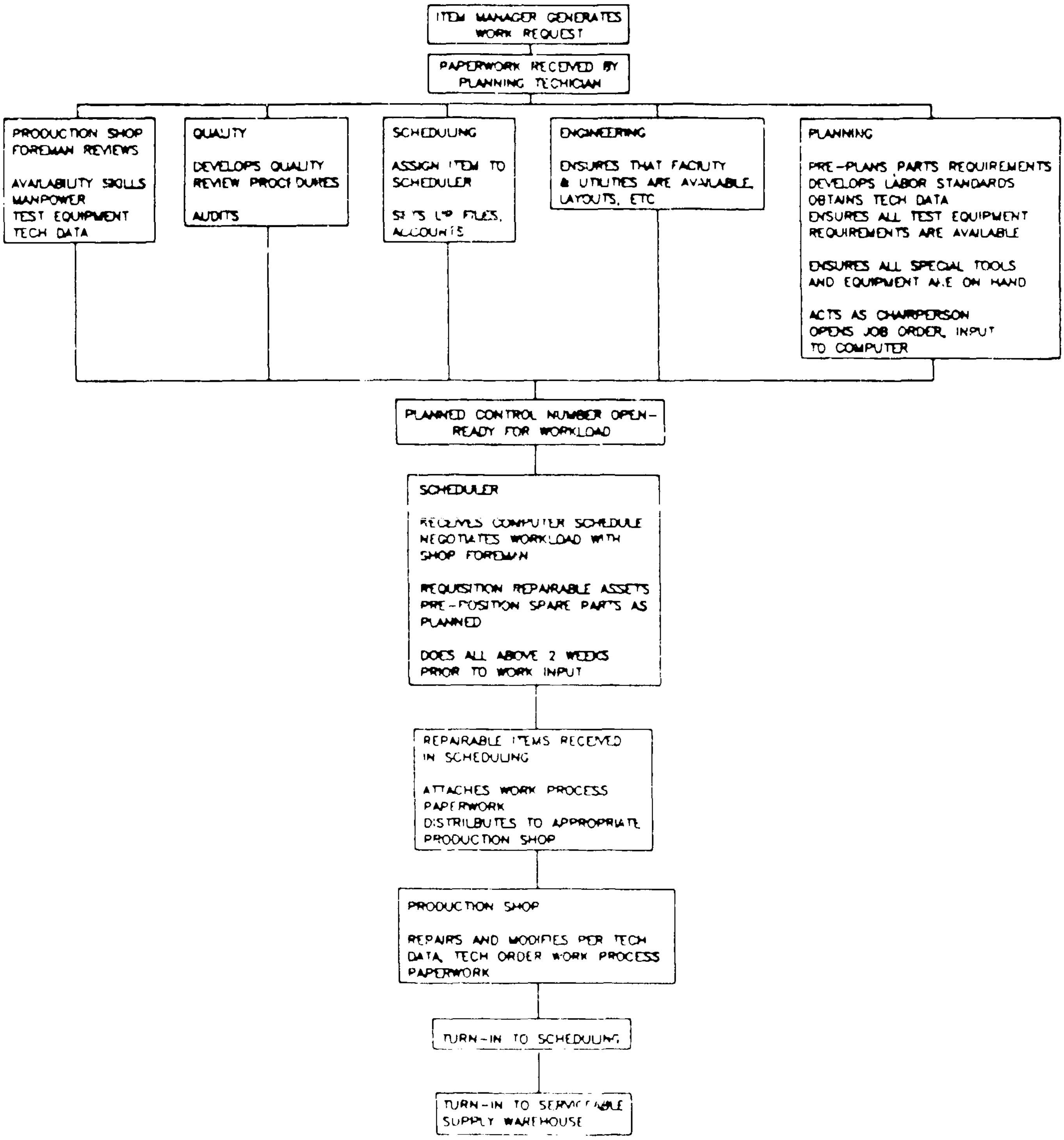


CHART 2

AIR FORCE LANDING GEAR REPAIR

-OGDEN AIR LOGISTICS CENTER INDUSTRIAL PRODUCTS AND LANDING GEAR DIVISION-

OO-ALC/MAN

BY: LT COLONEL TOM HRUSKOCY

I'm Lt Col Tom Hruskocy, Deputy Chief of the Industrial Products and Landing Gear Division at Hill Air Force Base, Utah. Our division is an integral part of the Ogden Air Logistics Center as such is one of the five depot centers which comprise the Air Force Logistics Command. Our division at Ogden is tasked with the overhaul and repair of a wide range of commodities in use throughout the Air Force, but our biggest task is the overhaul of the landing gear systems of some 28 different aircraft weapon systems. For that reason this division represents the largest landing gear overhaul facility in the world.

Now you may ask, "Why do we have such and operation?" The answer is threefold: Safety of aircrews, reliability and readiness of aircraft, and economics of operation. Now let me expand on those items a bit. First and foremost is safety of operations. As you can imagine, the landing gear of our aircraft are subject of quite abusive use. They sustain wear and tear from dirt field operations, landing on many different types of runways, some good, some bad, and they experience all kinds of landings, again some good, some not so good. After years of this kind of wear, the landing gear system literally wears out to the point where it becomes questionable as to how safe it may be or how reliable it is. With the concept of readiness in the Air Force we must be in a position to expect 100% reliability from our landing gear systems. With this background in mind, consideration must then be given to how do we go about restoring an aircraft's landing gear system. Do we buy a new set once the original wears out? In the case of a C-5 aircraft, one gear would cost $166,000. The other option is to rebuild the original gear, and this is exactly what we do at the Ogden Air Logistics Center. Every aircraft landing gear is rebuilt in the Industrial Products and Landing Gear Division at a cost of approximately 1/6 of that of the original set. In this way we can produce a like-new landing gear system without having to absorb the costs associated with new forgings, escalating costs and the vagaries of contractor and contracting administration.

The next question you might ask is, "Just what is landing gear?" Many varied parts comprise a single landing gear system and there are many different types. For example, we work with types as large and complex as that of a C-5

which is about 15 feet in length, down to that of the T-38 which is only about 4 feet long. We produce as few as one a year for such aircraft as the C-47 and into the hundreds as is the case with the F-4. The basic landing gear system we work with, however, is composed of the strut, the brake, and the wheel. Each of these items is overhauled individually. So you can readily see that these items have a critical impact on how safe we can operate our aircraft fleet.

During fiscal year 1982 the Industrial Products and Landing Gear division produced over 2600 landing gear assemblies. At this point you're probably wondering just how we go about overhauling a landing gear system. We have a modern industrial plant whose sole purpose is to produce these landing gears. There are some 480 people who operate our plant and they cover a wide range of technical skills. The technicians themselves range from machinists, through pneudraulics specialists to electro platers. However, these people are backed up by a team of engineers, production controllers and support elements of many kinds.

In 1979 the entire overhaul facility was relocated under one roof which houses most of the 14 major processes which lead to a completely overhauled landing gear system. This industrial plant covers some 680,000 square feet and in terms of real estate and equipment is valued in excess of \$20 million. However, the increases in efficiency and operation returned nearly \$7 million in the first year of operation. One of the main features of this plant is the 1.5 mile overhead conveyor system which is computer-controlled. It moves most of the 25,000 plus landing gear components which are in process at any one given time. The plant also utilizes over 210,000 gallons of processing chemicals in the cleaning area and another 140,000 gallons in the electroplating facility.

There are three buildings which support the operation; first the overhaul facility, then the electro-plating operating and also the main support back shop, the manufacturing machine shop. Among these buildings, there are 14 major processes that take place. These processes are disassembly, chemical cleaning, abrasive blasting, heat treating, nondestructive inspection, evaluation and inspection, machining, shot peening, electro-plating, thermal coating, remachining, assembly, painting and distribution.

A landing gear would come to our division from the operation environment through the base supply and distribution system. All landing gear with the exception of the C-5 follow the same basic processes flow once they reach us. The first step in the flow occurs when they reach the initial staging area where they are uncrated and the disassembled. In disassembly the mechanics will totally dismantle the landing gear. Separate lines are run for the strut, the

brake, and the wheel. These items are taken apart down to the smallest nut and bolt. A few items are discarded here but most will follow through the entire overhaul process. The last stage of the disassembly process will find each component of the landing gear raised onto the overhead computer-controlled transport system. The landing gear is now ready for the next phase of the overhaul process.

One of the main reasons for the overhead conveyor system is to minimize the contact of workers with the chemicals that are necessary for the cleaning operation. The chemical cleaning is the next step in the process. The landing gear components will now spend varying amounts of time in the chemical vats to clean the deposits of grease, dirt, sand, and oil from several years of accumulation. Later chemical processing will remove all paint and corrosion prevention coatings from the landing gear and clean the gear components to the base metal. Having been chemically stripped, the components are now ready to move on in the process.

The chemically cleaned parts are blasted with a dry abrasive to remove any residual paint or residue. It is imperative that the parts be clean to allow a good inspection later in the process. There is, however, the potential for undesirable effects of the chemical process on the steel parts unless certain things are done to the gear components.

Once abrasive blased the steel parts are baked at 375 degrees F for four hours to relieve service induced stresses and to bake out any hydrogen taken into the part during the chemical cleaning and paint stripping process. Excess hydrogen remaining in the high strength steel causes the steel to become brittle and subject to hydrogen embrittlement failure when stressed under normal service conditions.

Now the landing gear components are ready for the scrutiny of man and machine which will tell us just what kind of conditions the components are really in and what must be done to restore them to like-new condition. The first of these inspection techniques is that of nondestructive inspection. Through the use of several different dye penetrants, electronic and magnetic principles the metals will be searched for defects, cracks, and stresses which indicate that the item may not be suitable for further use or is not repairable under the overhaul guidelines. Once the nondestructive inspection has taken place, further evaluation of each landing gear component will take place. The main wear on the gear components occurs in places where metal-to-metal contact takes place. These are the key areas which are then measured by highly competent technicians who will further make the determination as to whether a component is repairable or subject to condemnation. At this critical point in the overhaul process, the inspectors will condemn approximately 7% of the components, find another 8% of them to be good as is, but some 85% will require the actual restoration to make the final landing gear product like new.

Let's move to the next stage in the process which is where the 85% group of components will be processed. One of the main activities involved with the restoration of components takes place in the electro-plating facility. This facility will do four major processes before restoring a component to like-new condition. The first of these processes will be to strip the damaged wear surfaces of the component to base metal. These damaged chrome surfaces will be removed by electrolytic chemical stripping. Once all the old chrome is removed, the base metal will be machine-ground to true the surface and remove damage or corrosion. A temper etch inspection is performed on all ground surfaces to insure no degradation to the steel parts occurred due to improper grinding. Next the base metal is shot peened with cast steel case shot to lengthen the fatigue life of the part. Following the shot peening process, the surface is electrolytically chrome plated. This electro-plating process will take up to 24 hours of immersion in a chromic acid bath. After the plating has taken place, the component will once again be subjected to the machining process where the plated chrome will be ground down to the level at which the component was when it was brand new. The remaining bare metal surfaces are recadmium plated on steel parts and reanodized on aluminum parts for corrosion protection. With the corrosion protection coatings in place, new bushings with original dimensions and tolerances are installed at wear joints and lugs. The landing gear part has now been fully repaired and is ready to be reassembled.

The thousands of components undergoing the above process are all funneled into the assembly staging area after they have been repaired. When they reach the staging area, material handling employees match up all the items that are necessary to reconstruct a full landing gear system. All the components for a single gear are loaded onto a cart and transported to the assembly section where journeymen will reassemble the components. They will perform operational tests on the new landing gear to be certain that it holds hydraulic pressure, operates as programmed and functions perfectly. Only then is it ready for the final process in the overhaul flow.

The last phase in the overhaul is the cosmetic portion, but nevertheless important. To protect the finished product from the rigors of weather and wear, the landing gear must be painted and identified. The landing gear will receive three coats of paint, one primer and two top coats of polyurethane. Finally, the gear will be decaled to identify it as to part number, date, source of overhaul, and other information. At last, the landing gear has finished the process. It has come in as a worn, well used item. It leaves with generally the same major components, but fully restored to provide years of useful safe service. It is restored to fully safe proportions, ready to provide the 100% reliability and readiness sought after. The entire

operation has been accomplished at 1/6 the cost of replacing the landing gear. But, one last requirement exists. The item must be moved expeditiously to the place it is needed. It could be for a fighter stationed at Osan OB, Korea, or a C-141 at the Warner Robins Air Logistics Center Periodic Depot Maintenance Facility in Georgia. The gear will in either case be sped to its destination, again through the Air Force's supply and distribution system. At last the cycle is complete.

The overhaul of landing gear systems at the Ogden Air Logistics Center is indeed a unique and remarkable system. It is responsive, highly productive and a capability which has stood the test of providing safe, reliable, and economic restoration of a critical part of the Air Force capability. The men and women represent a proud and dedicated work force. They will continue to provide innovative methods to sustain the landing gear overhaul process and insure its productivity. In the meantime, the Air Force is proud of this capability and will continue to use it to produce ready aircraft in the defense of the United States.

—ABSTRACT—

NAVY DEPOT PROCESSES - NARF, ALAMEDA

By: W. Foster

Mr. Foster discussed repair processes for missiles at Alameda. The Sidewinder, Tarter, Terrier, and Bullpup programs began in 1965. Currently, Alameda remanufactures the Phoenix weapon, Sparrow, and Shrike, and is currently competing for AAMRAM, Harm, and advanced Sparrow. Alameda has 80,000 square feet under roof currently dedicated to missile production, which will be expanded to meet current new commitments. The repair process includes: (1) induction; (2) uncanning and inspection; (3) modification/repair; (6) inspection; (7) test; (8) reassembly; (9) stress screening (temperature and vibration); (10) surface preparation; (11) painting; (12) final acceptance test; (13) final inspection (cosmetic); and (14) packaging and preservation.

AIR INDUSTRIAL DEPOT OPERATIONS
NAVAL AIR REWORK FACILITY, CHERRY POINT
BY: THOMAS TOLSON

AIRFRAME REPAIR

FUNCTIONAL AREAS:

- DISASSEMBLY/ASSEMBLY
- SHEET METAL
- STRIP/FINISH/PAINT
- MACHINING
- TESTING
- COMPOSITES

DISASSEMBLY/ASSEMBLY

— REMOVAL/INSTALLATION OF MAJOR ASSEMBLIES

- WINGS
- STABILIZERS
- ENGINES

— REMOVAL/INSTALLATION OF COMPONENTS

- AVIONICS
- HYDRAULIC
- PNEUMATIC
- MECHANICAL

— DISASSEMBLE TO:

- ROUTE FOR REWORK
- REPAIR/REWORK/MODIFY
- GAIN ACCESS
- TEST/CHECK
- TREAT CORROSION

SHEET METAL

- FABRICATION OF STRUCTURAL REPAIR AND OTHER METAL PARTS
- REPAIR OR REPLACEMENT OF SKIN PANELS, RIBS, STRINGERS, SPARS, ETC.
- REPAIR OR MODIFICATION OF AILERONS, FLAPS, SLATS, FINS, STABILIZERS, LEADING EDGES, FLOOR BOARDS, ACCESS PANELS
- REMOVE/TREAT CORROSION

STRIP/FINISH/PAINT

- CHEMICAL STRIPPING
- DEGREASING
- BLASTING
- TANK SOAKING
- WATER SPRAY
- SCRAPING
- STEAMING
- MASKING
- SANDING
- SEALING/CORROSION TREATMENT
- PAINTING
- APPLY MARKINGS/DECALS

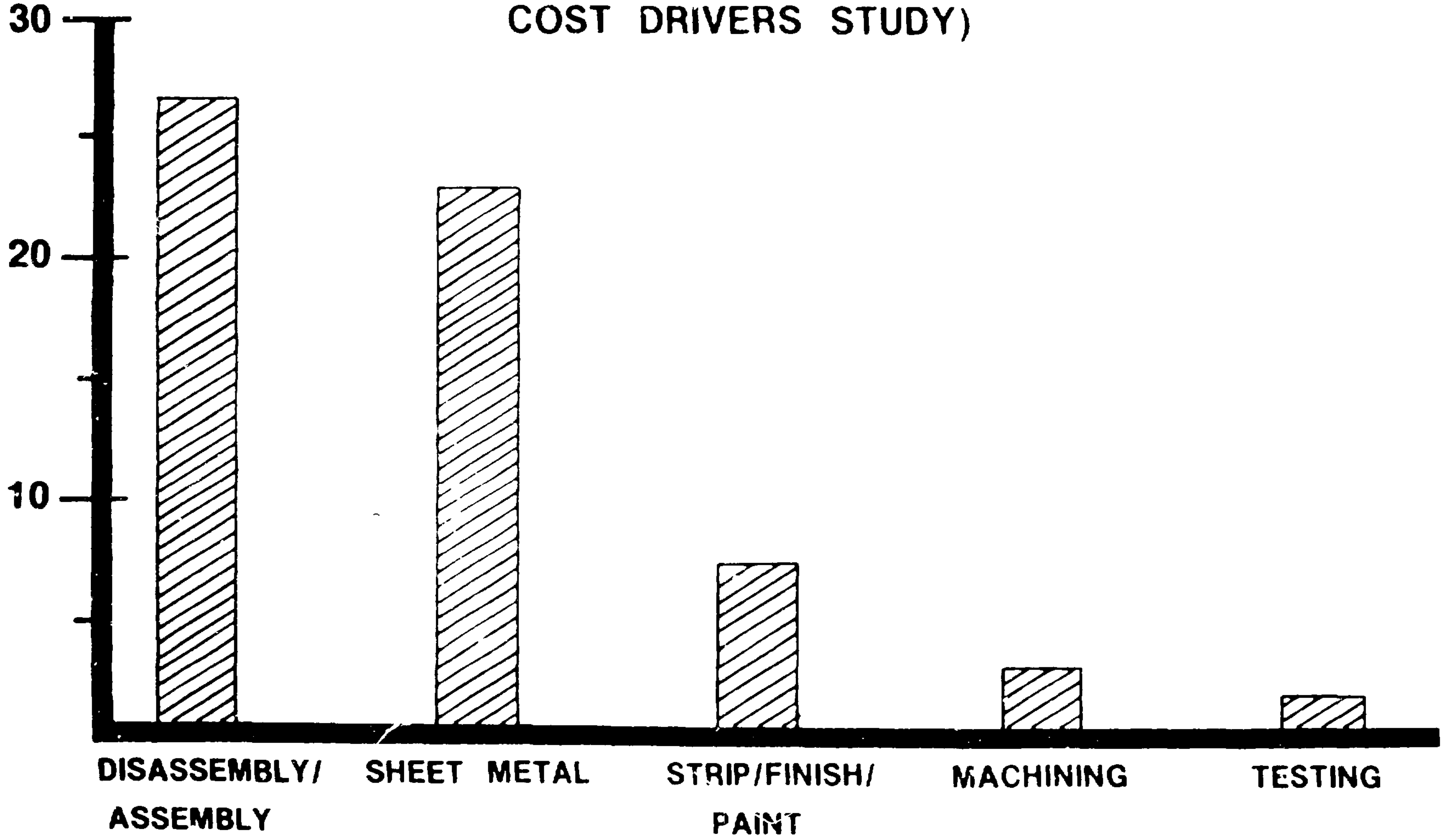
MACHINING

- GRINDING
- MILLING
- TURNING
- BORING
- DRILLING/SLOTTING
- FACING
- TAPPING
- COUNTER-SINKING
- HONING

TESTING (NDT/NDI)

- DYE PENETRANT
- MAGNAFLUX
- ZYGLO/FLUORESCENT PENETRANT
- ULTRASONIC
- RADIOGRAPHIC
- EDDY CURRENT

PERCENT OF TOTAL AIRCRAFT REWORK PROGRAM DIRECT LABOR (APPROXIMATE - DERIVED FROM 1979 MANUFACTURING TECHNOLOGY COST DRIVERS STUDY)



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100

NARF JACKSONVILLE

NAVAL AIR REWORK FACILITY
JACKSONVILLE
BY: L. WARD

STATISTICAL BACKGROUND

AIRCRAFT REWORKED: ------- A-7 P-3 (FUTURE F/A 18)

ENGINES: -- J-52 TF-41 TF-34 R-1820 (FUTURE F-404)

EMPLOYEES: ------------------------------ 3100

TRADES: ---------------------------------- 150

FACILITIES: ------------- 50 BUILDINGS ON 96 ACRES

LOCATION: ABOARD NAVAL AIR STATION, JACKSONVILLE, FL.

PAYROLL: ---------------- $80 MILLION ANNUALLY

STATUS: LARGEST INDUSTRIAL EMPLOYER IN NORTHEAST FL.

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NARF JACKSONVILLE

WORKLOAD (IN UNITS)

AIRCRAFT		ENGINES	
P-3	19	J-52	276
A-7	170	TF-41	181
		TF 34	68
		R1820	143
		TOTAL	668

COMPONENTS

68,970

NARF JACKSONVILLE

* AREAS WITH POTENTIAL ROBOTICS/AUTOMATION
** AREAS WITH INSTALLED AUTOMATION

PROCESS INFORMATION FY-84

PROCESS	DIRECT LABOR HRS/YR (K)	TOTAL COST/YR (K)	HAZARDOUS/ UNPLEASANT WORK ENV	LABOR SKILL REQ'D	RELEVANT TECHNOLOGY
*WELDING	44.4	$1,998	YES	HIGH	ROBOTIC, ELECTRON BEAM, LASER WELDING
**MACHINING	157.4	7,083	NO	HIGH	CNC/DNC/CAD/CAM/AUTOMATIC LOADERS
ENGINE DISASSEMBLY/ASSEMBLY	195.5	8,798	NO	LOW/HIGH	
*A/C & PARTS INSPECTION	88.8	3,996	NO	HIGH	COORDINATE MEASURING MACHINES, AUTO ULTRASONIC AND X RAY SYSTEMS
A/C DISASSEMBLY/ASSEMBLY	633.3	28,499	NO	LOW/HIGH	
*A/C & COMPONENT STRIPPING	103.3	4,649	YES	LOW	AUTOMATED SPRAY SYSTEMS, GANTRY TYPE, JOINTED TYPE
*A/C & COMPONENT PAINT & FINISH	132.7	5,972	YES	MODERATE	
*SHEET METAL REPAIR & MFG.	165.5	7,448	NO	MODERATE	CNC/DNC/LASER CUTTING
*CLEANING	39.0	1,755	YES	LOW	AUTOMATED SYSTEMS
**PLATING	29.5	1,328	YES	HIGH	COMPUTERIZED TIMING, TEMP., CURRENT CONTROL AND PARTS HANDLING
**ENGINE TEST	29.8	1,341	NO	HIGH	AUTOMATED, COMPUTERIZED TEST SYSTEMS
*ENGINE BLADE REPAIR & BALANCING	57.0	2,565	NO	MODERATE	AUTOMATED SYSTEMS
HEAT TREATING/FORGING	13.6	612	YES	MODERATE	
*PLASMA SPRAY	12.1	545	YES	HIGH	ROBOTIC REMOTE CONTROL
ENGINE FUEL COMPONENTS REPAIR	86.1	3,875	NO	HIGH	
*PACKAGING	30.5	1,373	NO	LOW	AUTOMATIC PALLETIZERS/PACKAGERS
ELECTRICAL CABLE REPAIR/FABRICATION	34.7	1,562	NO	MODERATE	
FIBERGLASS/PLASTIC REPAIR	26.8	1,206	YES	HIGH	COMPOSITE TECHNOLOGY
HYDRAULIC COMPONENTS/VALVES REPAIR	52.7	1,412	NO	HIGH	
LANDING GEAR ASSEMBLY/DISASSEMBLY	11.4	513	NO	MODERATE	
**BEARINGS REFURBISHMENT	10.0	450	NO	HIGH	AUTOMATED CLEANING/INSPECTION LINE

TF-41 ENGINE

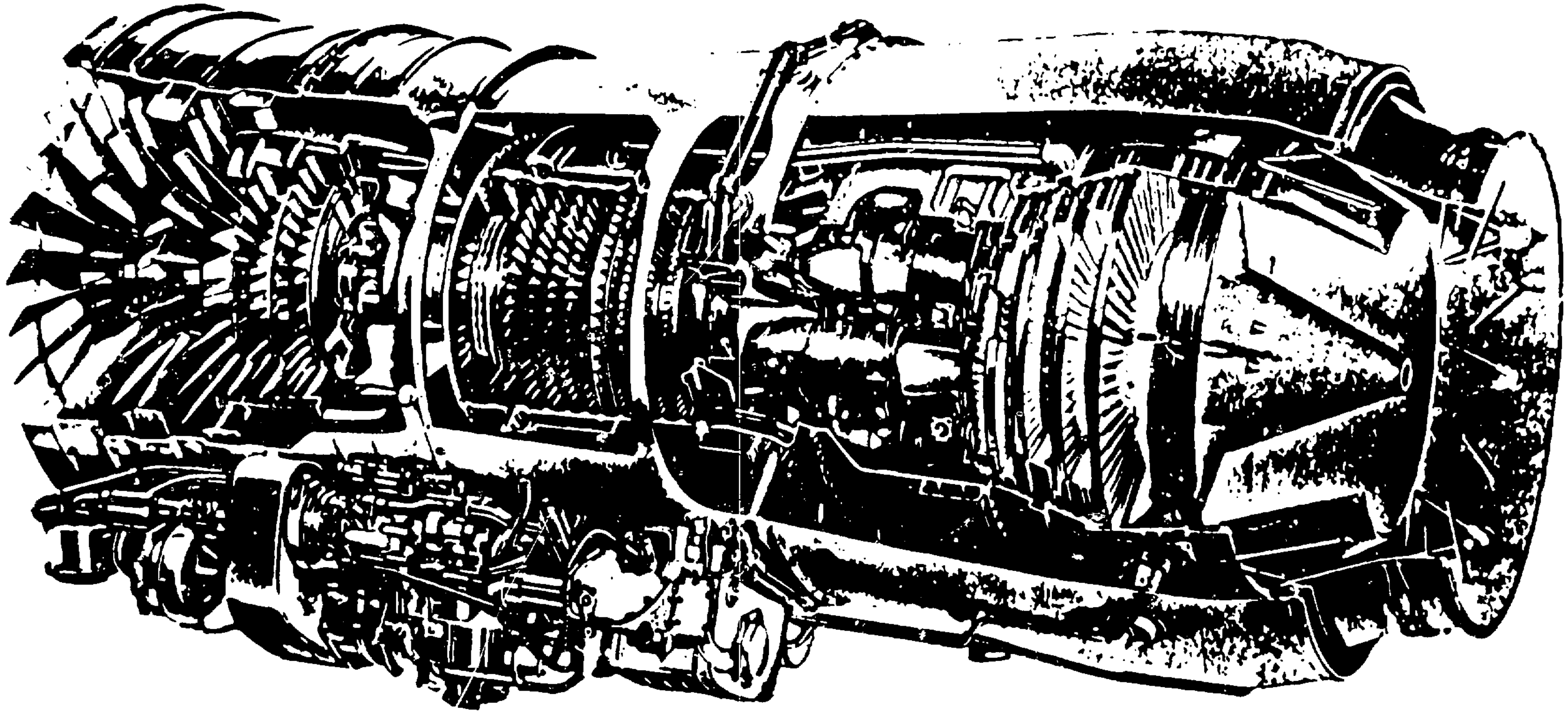
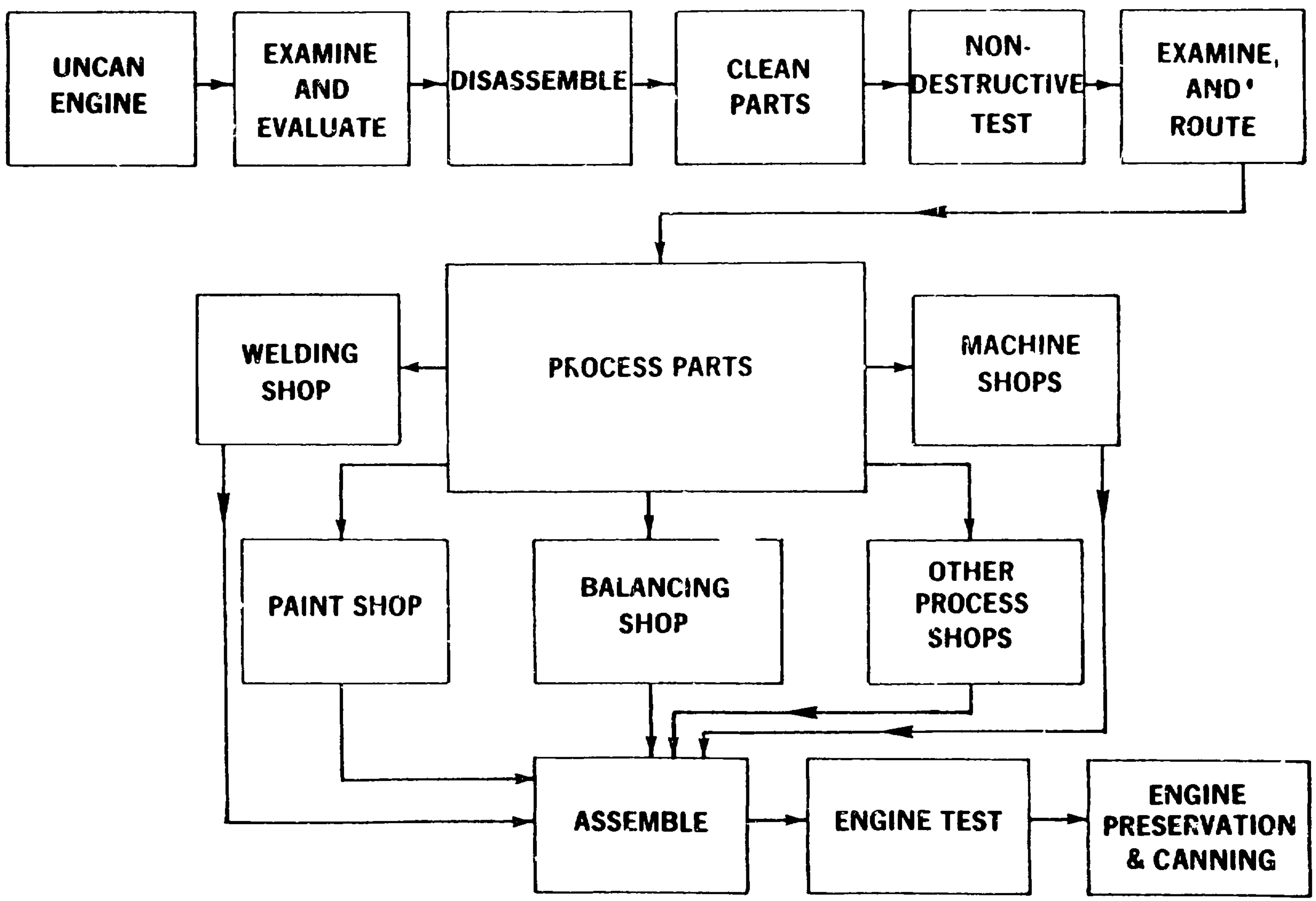
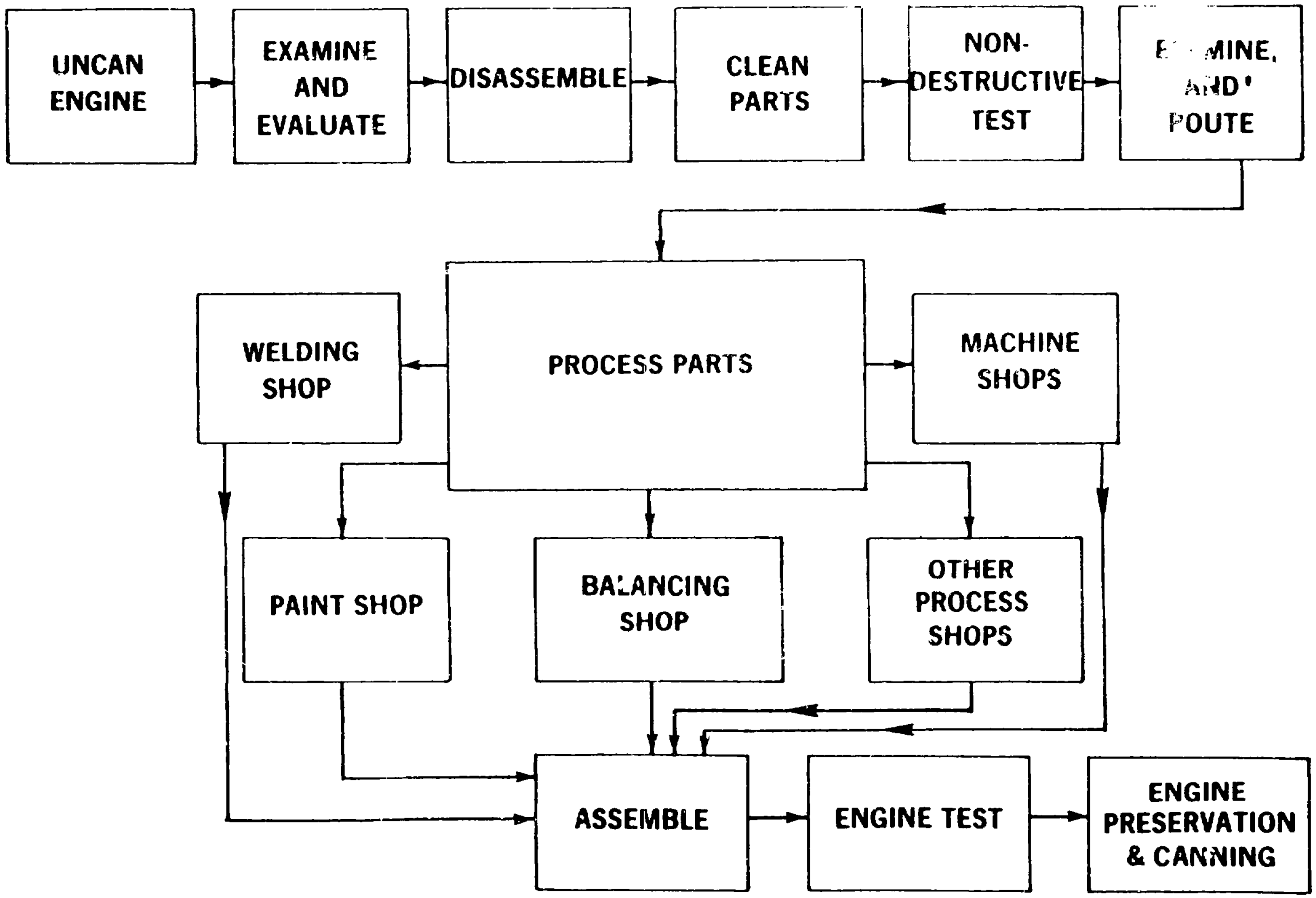


Figure 1-3. Cutaway of TF41 Engine

J-52 ENGINE PROCESS ANALYSIS



J-52 ENGINE PROCESS ANALYSIS



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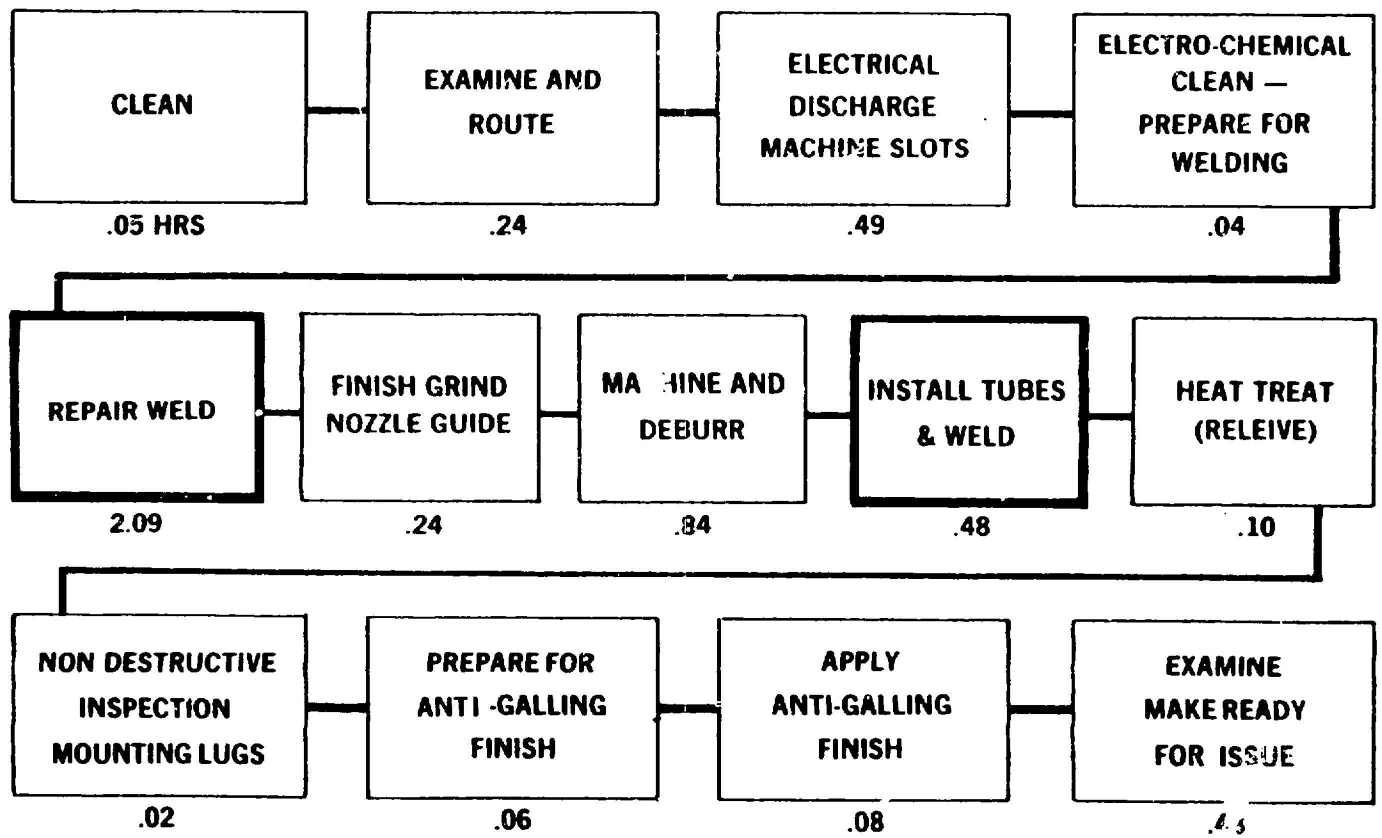
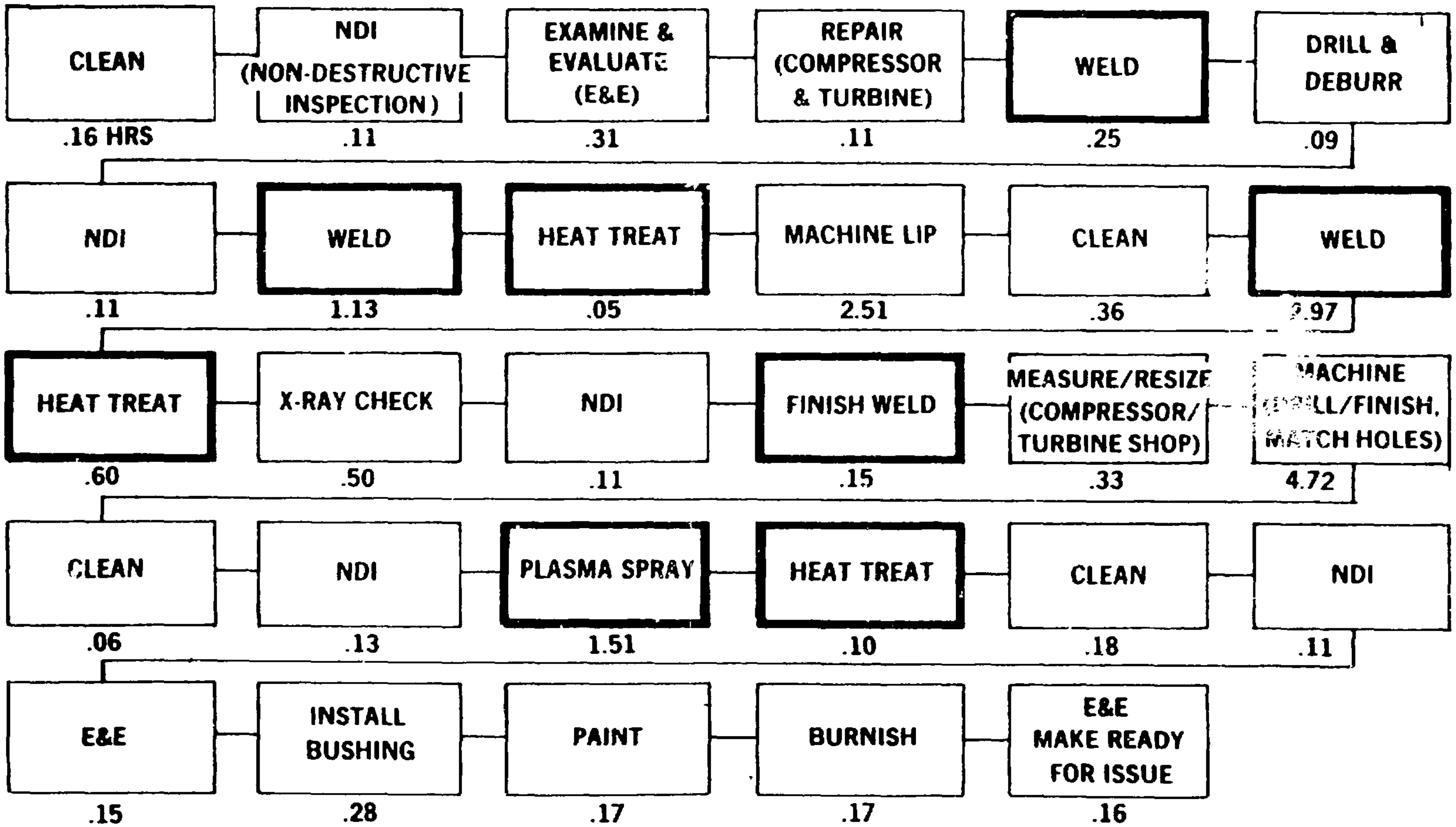
PROCESS ANALYSIS:
J-52 COMBUSTION CHAMBER (BURNER CAN)



QUANTITY: 9/ENGINES
PROCESSING TIME: 5.21 HRS EACH
TOTAL ANNUAL DIRECT LABOR HOURS: 12,941
TOTAL ANNUAL DIRECT COST: $582,345

PROCESS ANALYSIS:
J-52 TURBINE EXHAUST CASE



DIRECT LABOR HOURS: 17.59

ANNUAL WORKLOAD: 276 UNITS

TOTAL ANNUAL COST: $217,847

NARF JACKSONVILLE

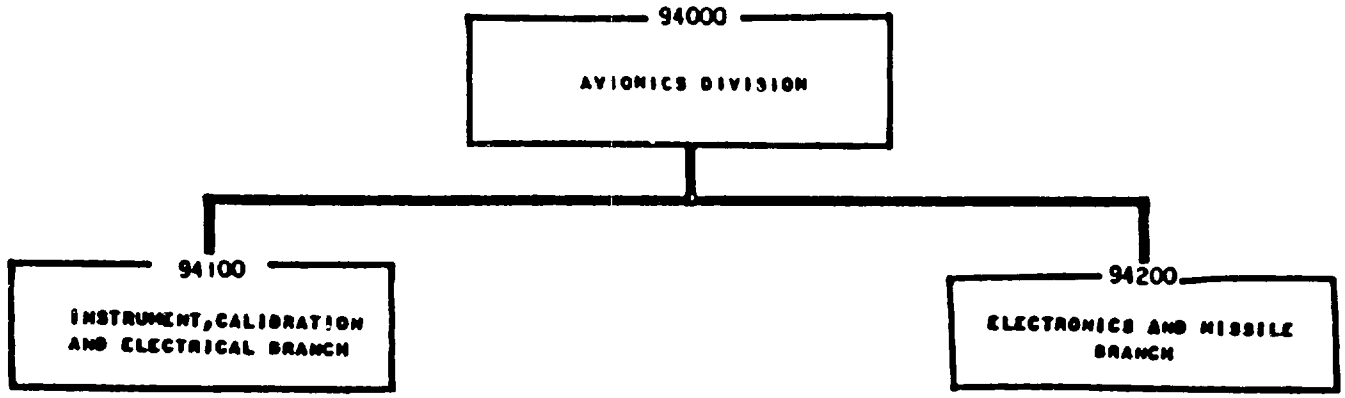
DIRECT LABOR ENGINE STANDARD HOURS DISTRIBUTION (PERCENT)

J-52 ENGINE

EXAMINATION & EVALUATION	3.5
INDUCT/DISASSEMBLY	5.9
CLEANING	6.3
NON-DESTRUCTIVE TESTING	5.4
PARTS PROCESSING/MANUFACTURING	24.5
MACHINE	16.3
ACCESSORIES PROCESSING	14.6
COMPRESSOR & TURBINE BALANCE	9.9
J-52 ASSEMBLY	7.7
TEST	5.0
PRESERVATION	0.9
	100.00

PROCESS TIME J-52 ENGINE: 31 DAYS

NARF NORFOLK DEPOT OPERATIONS
NAVAL AIR REWORK FACILITY, NORFOLK
BY: WILLIAM MAXWELL



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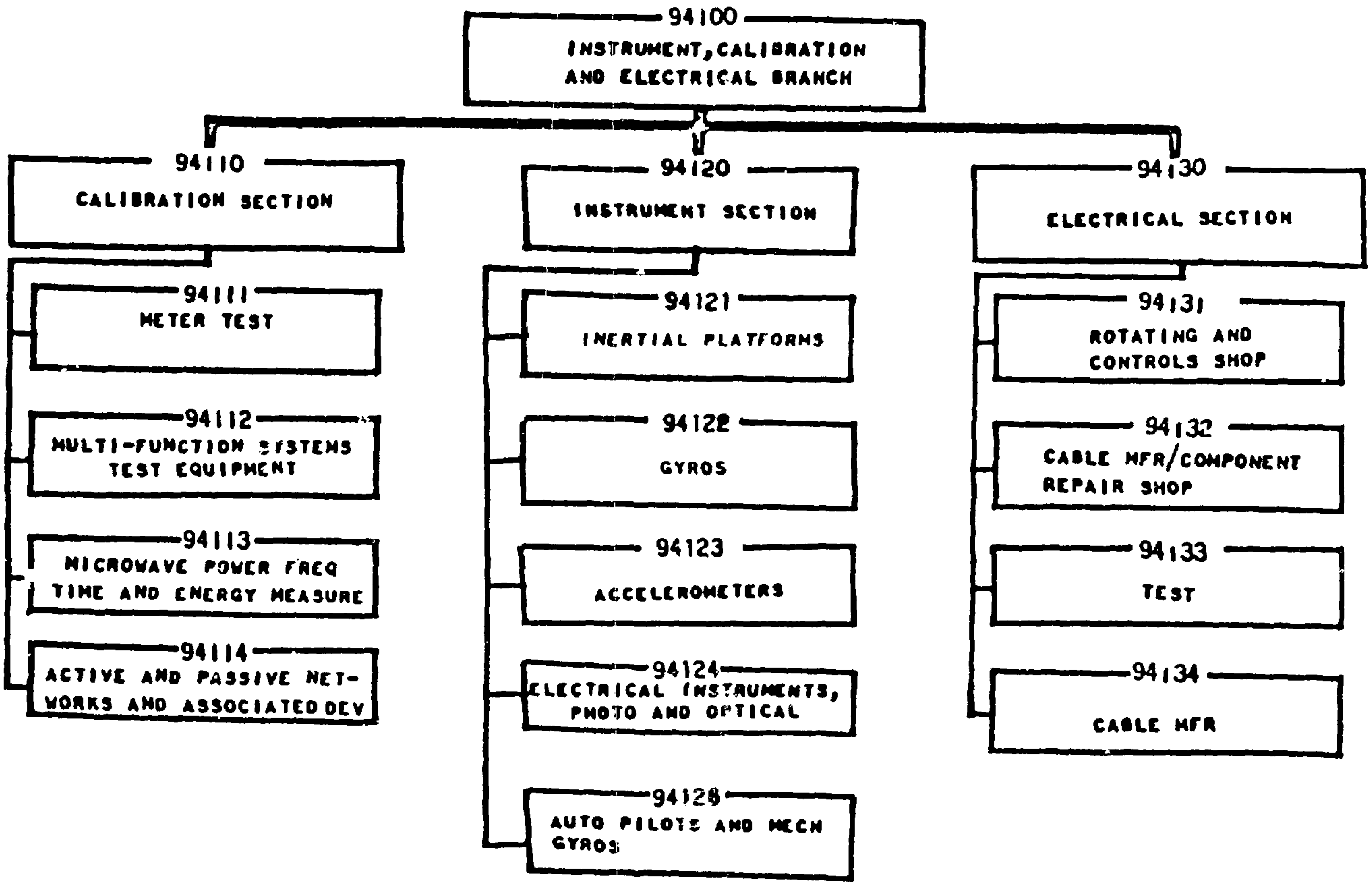
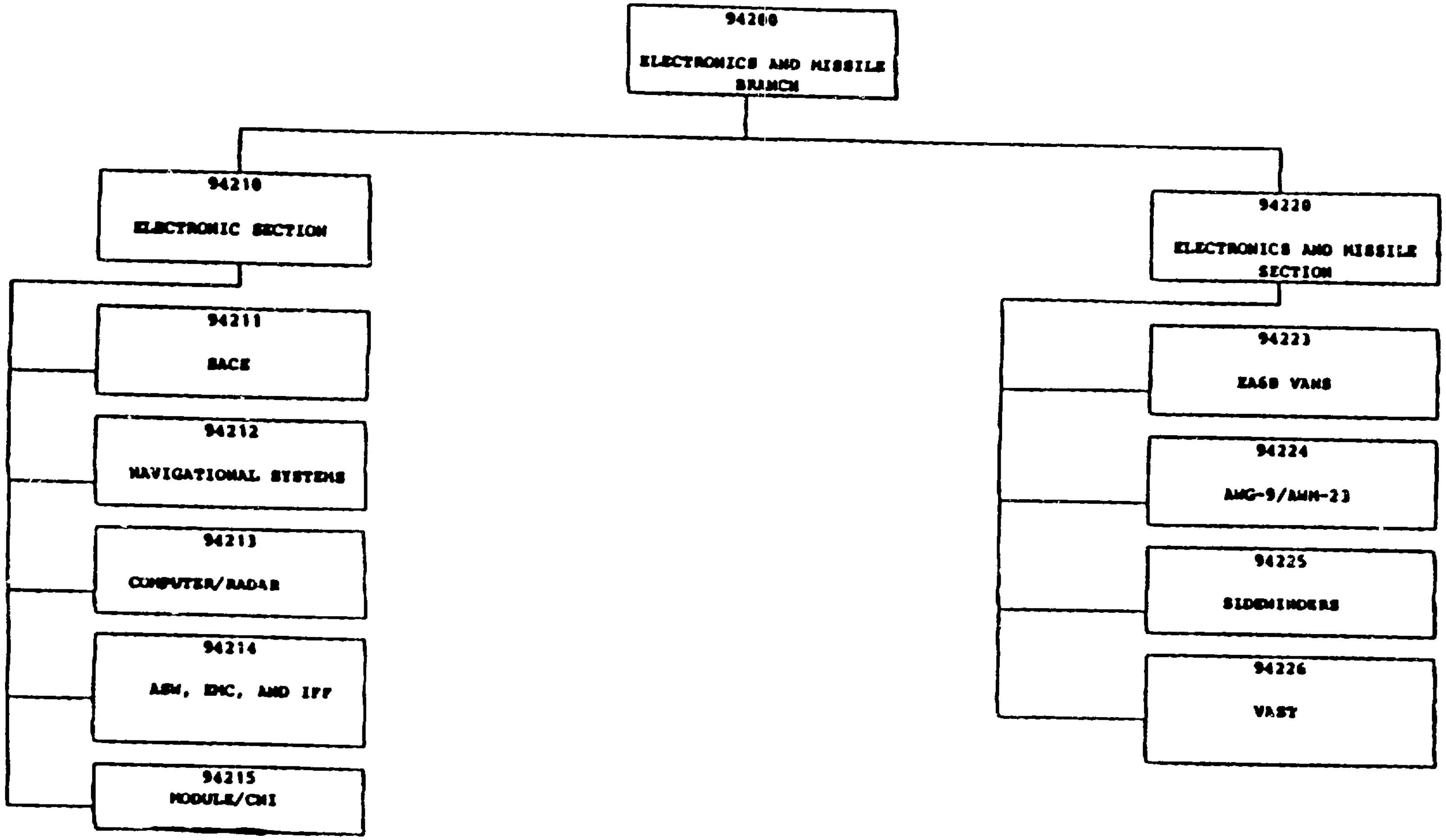

94100
INSTRUMENT, CALIBRATION AND ELECTRICAL BRANCH
94110
CALIBRATION SECTION
94111
METER TEST
94112
MULTI-FUNCTION SYSTEMS TEST EQUIPMENT
94113
MICROWAVE POWER FREQ TIME AND ENERGY MEASURE
94114
ACTIVE AND PASSIVE NETWORKS AND ASSOCIATED DEV
94120
INSTRUMENT SECTION
94121
INERTIAL PLATFORMS
94122
GYROS
94123
ACCELEROMETERS
94124
ELECTRICAL INSTRUMENTS, PHOTO AND OPTICAL
94128
AUTO PILOTS AND MECH GYROS
94130
ELECTRICAL SECTION
94131
ROTATING AND CONTROLS SHOP
94132
CABLE MFR/COMPONENT REPAIR SHOP
94133
TEST
94134
CABLE MFR

CALIBRATION
- METERS
- TEST PANELS
- MICROWAVE GENERATORS
- PASSIVE NETWORKS AND ASSOCIATED DEVICES

INSTRUMENT SECTION
- INERTIAL PLATFORMS
- GYROS
- ACCELEROMETERS
- ELECTRICAL INSTRUMENTS, PHOTO AND OPTICAL
- AUTOMATIC PILOTS

ELECTRICAL SECTION
- ROTATING AND CONTROLS, GENERATORS, MAGNETOS
- CABLE MANUFACTURE


94200
ELECTRONICS AND MISSILE BRANCH
94210
ELECTRONIC SECTION
94211
BACE
94212
NAVIGATIONAL SYSTEMS
94213
COMPUTER/RADAR
94214
ASW, EMC, AND IFF
94215
MODULE/CMI
94220
ELECTRONICS AND MISSILE SECTION
94223
EA6B VANS
94224
AWG-9/AWM-23
94225
SIDEWINDERS
94226
VAST

ELECTRONICS SECTION

-FIRE CONTROL RADAR

- PLOTTING AND COMPUTER SYSTEMS
- TELEVISION CAMERA AND DISPLAY SYSTEMS
- FIRE CONTROL SYSTEMS
- ECM SYSTEMS
- ASW SYSTEMS
- IFF SYSTEMS
- NAVIGATIONAL SYSTEMS
- MODULE/SRA REPAIR

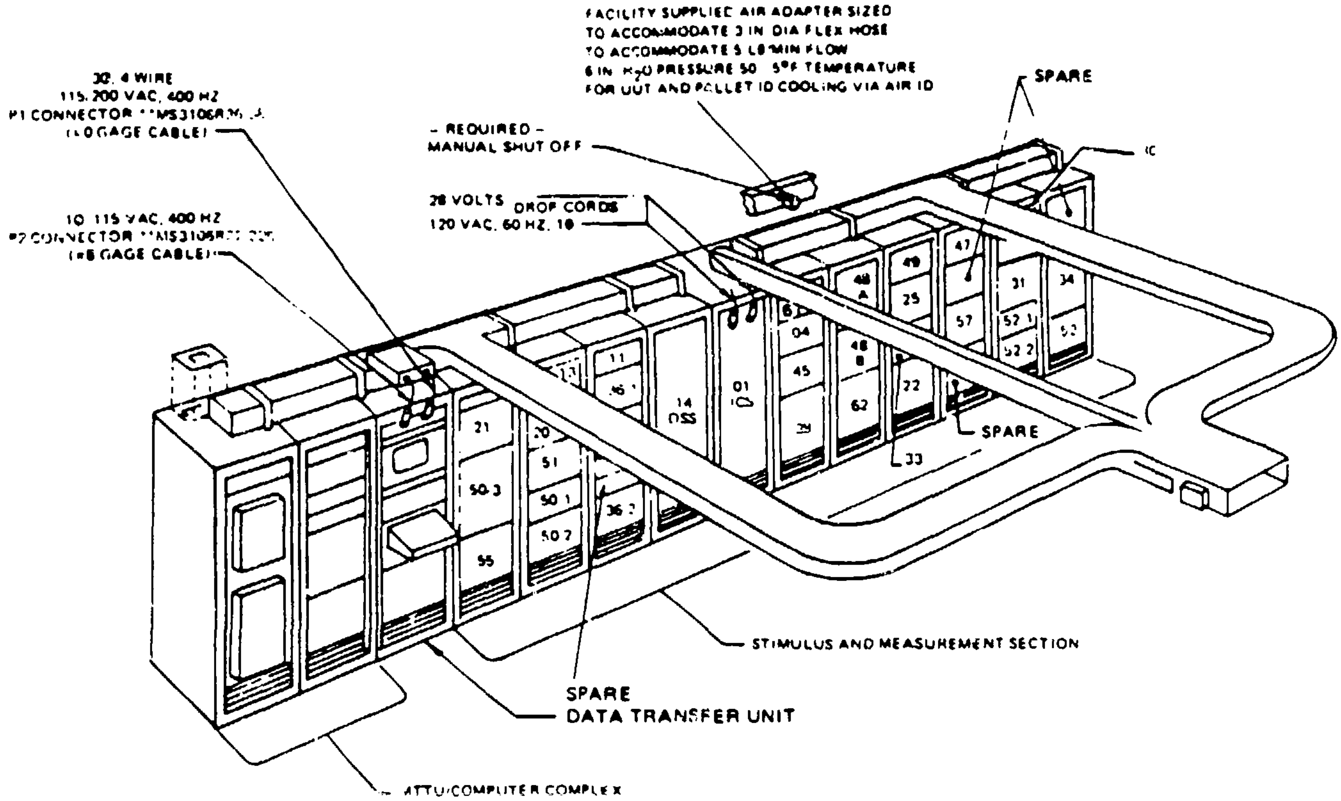
ELECTRONIC AND MISSILE SECTION

- PRINTED CIRCUIT BOARDS
- PROGRAMMING OF ATE
- VAST, USE OF AND REPAIR OF
- SIDEWINDER MISSILES

AUTOMATIC TEST EQUIPMENT

- VAST
- CAT IIID
- SACE
- SATS
- EMTC

VAST



BUILDING BLOCK	TITLE	PRD SPECIFICATION	BUILDING BLOCK	TITLE	PRD SPECIFICATION
01	INTERFACE & CONFIG SWITCH	37932	45	RMS VOLTMETER	3791?
04	CONTROL SWITCH	37863	48 (A & B)	PROGRAMMABLE SCOPE	37943
10	DIGITAL MULTIMETER	37912	49	RATIO TRANSFORMER	37865
11	FREQ & TIMER INTERNAL METER	37913	50 (-1, -2, -3)	DC POWER SUPPLY, 0 1-35 VOLTS	37909
13	DELAY GENERATOR	37940	51	DC POWER SUPPLY, 22 32 VOLTS	37908
20	SIGNAL GENERATOR, 0.1 HZ-50 KHZ	37906	52 (-1 & -2)	DC POWER SUPPLY, 30-500 VOLTS	37907
21	SIGNAL GENERATOR, 10 KHZ-40 MHZ	37923	53	DC POWER SUPPLY, 015 KV-1 KV	37910
22	SIGNAL GENERATOR, 20 MHZ-500 MHZ	37924	56 (A & B)	AC POWER SUPPLY	37945
25	SIGNAL GENERATOR, 4 GHZ-8 GHZ	37926	61	PRECISION RESISTIVE LOAD	37959
30	SERVO ANALYZER	37922	62	HIGH-POWER RESISTIVE LOAD	37947
31	SYNCHRO/RESOLVER STD	37935	14	DIGITAL SUBSYSTEM	37955
33	PHASE SENSITIVE VOLTMETER	37921		INPUT/OUTPUT CONSOLE	37896
34	PRESSURE GENERATOR	37029		DATA TRANSFER UNIT	37905
36 (-1 & -2)	FUNCTION GENERATOR	37942		MAGNETIC TAPE UNIT	37886
38	LOW FREQUENCY WAVE ANALYZER	37900	57	RF MEASUREMENT AUGMENTER	
40	PULSE GENERATOR	37931			

** CONNECTORS ARE CONTRACTOR FURNISHED EQUIPMENT WIRE WITH 15 FOOT CABLE EACH.

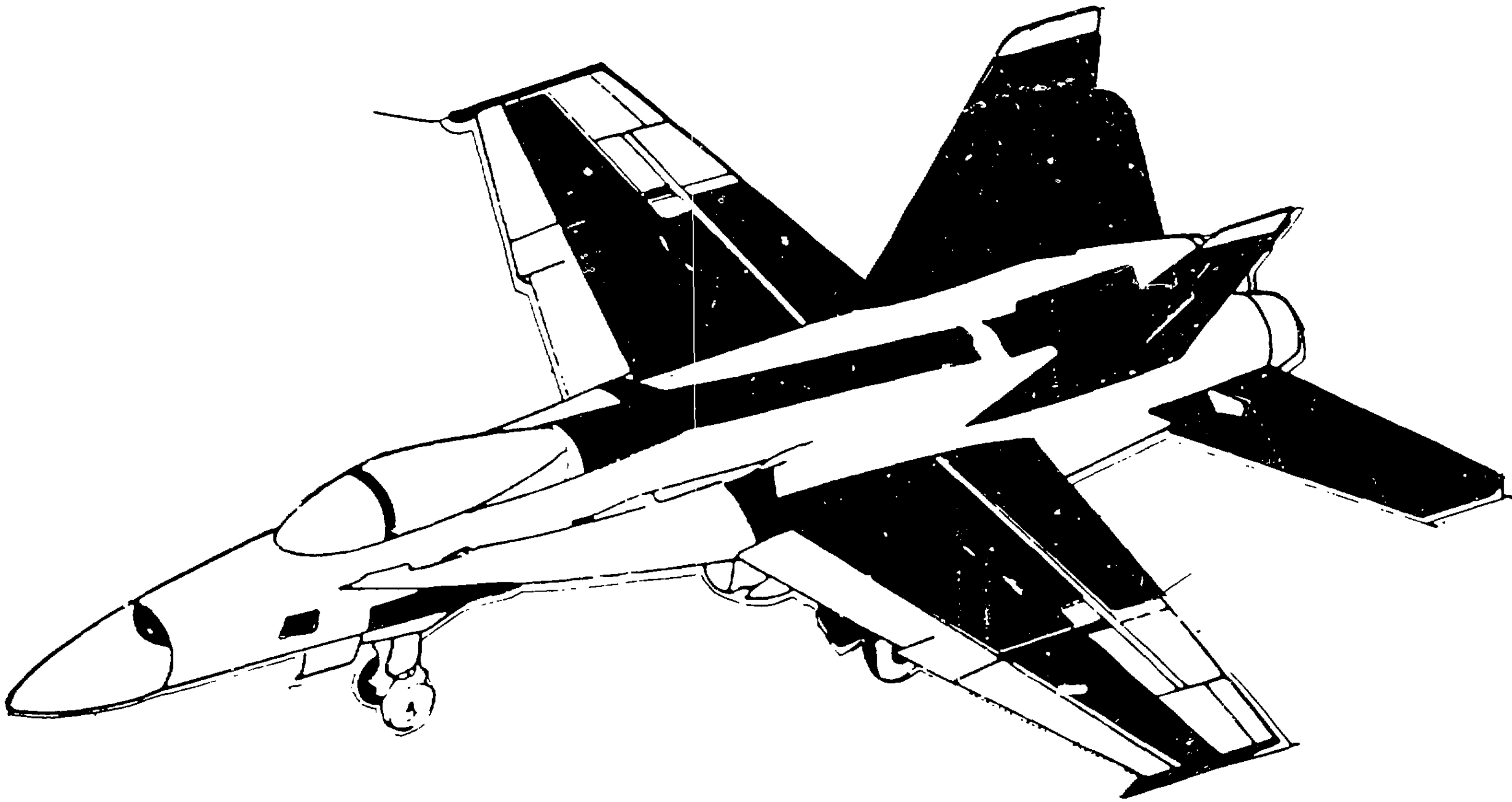
COMPOSITE REPAIR PROCESSING

NAVAL AIR REWORK FACILITY, NORTH ISLAND

BY: CAPTAIN PHILIP MONROE

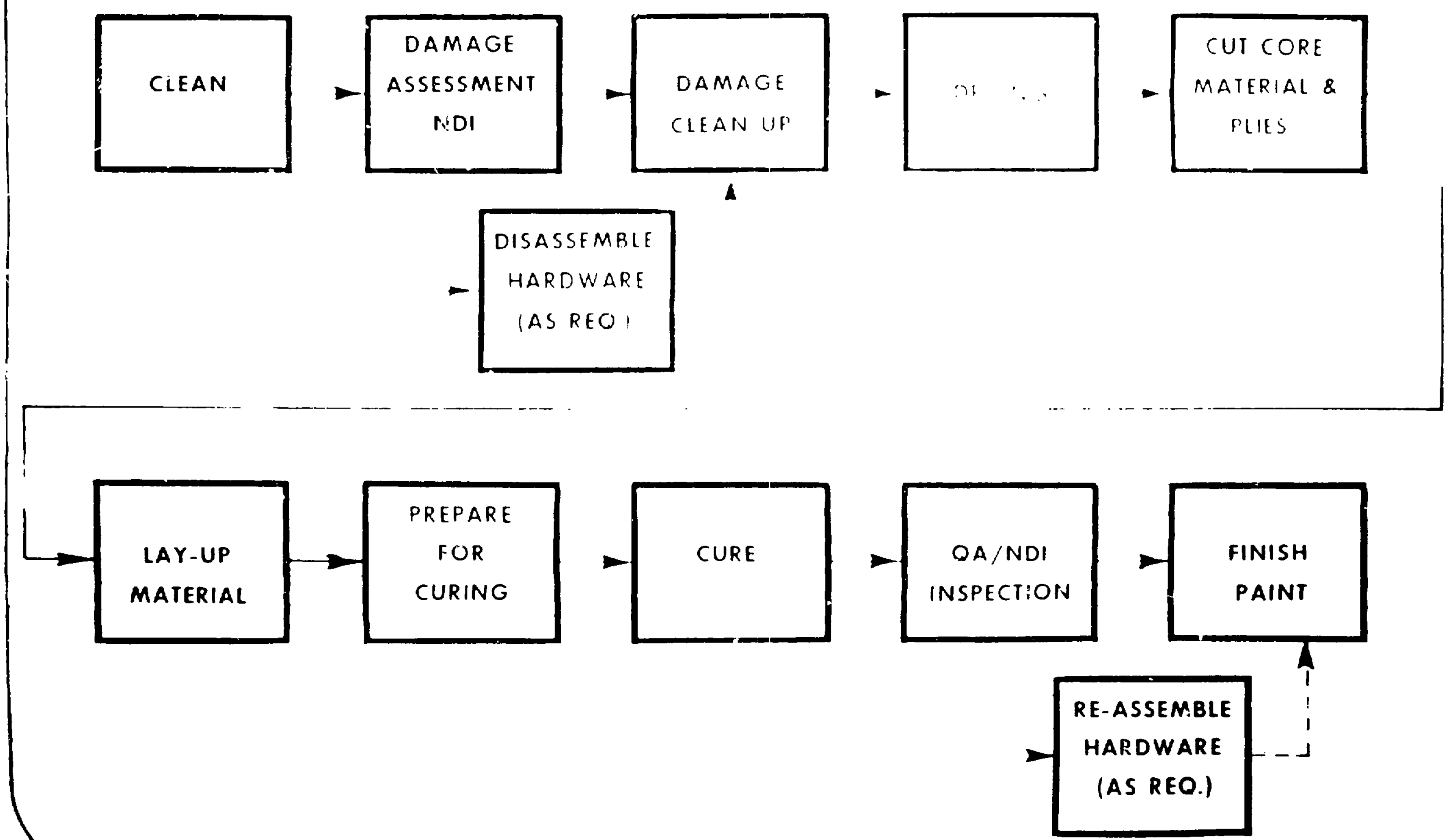
F/A-18 GRAPHITE/EPOXY AREAS

(45% OF ENTIRE AIRCRAFT SURFACE)



GRAPHITE/EPOXY

TYPICAL COMPOSITE REPAIR PROCESS



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EQUIPMENT

- ULTRASONIC "A" & "C" SCAN
- X-RAY
- CORE CARVER
- DRYING OVENS
- PRE PREG CUTTER
- AUTOCLAVES
- RESTRAINT & ASSEMBLY FIXTURES
- HANDLING DOLLIES
- TOOLING & MISC.

POTENTIAL ROBOTICS APPLICATIONS

- ULTRASONIC "C" SCANNING
- X-RAY SCANNING
- LAY UP OF COMPOSITE PLIES

--ABSTRACT--

NAVY DEPOT PROCESSES - NARF, PENSACOLA

By: Christopher Dunlap

Mr. Dunlap gave a presentation on dynamic components rework remanufacturing (helicopter components). Pensacola is the Navy Helicopter Depot, with one production division doing dynamic component remanufacturing (450 employees). Dynamic components consist of everything in the power train and drive system. Systems supported are the H-2, H-3, and H-53 helicopters. Products produced are the main rotor head, tail rotor head, etc. A single component may exceed $1M in original acquisition cost. Charts were presented on workload and the process flow, which includes the steps of (1) induction; (2) disassembly; (3) cleaning; (4) examination and NDT; (5) rework; (6) reinspection; (7) testing; and (8) pack and preservation. The high skill level of personnel working on dynamic components was stressed.

PROCESS OVERVIEW - CHARLESTON NAVAL SHIPYARD

BY: BILL NUGENT

MISSION

- REPAIR SURFACE CRAFT
- REPAIR/REFUEL SUBMARINES

ENVIRONMENT

. WORK FORCE	8,200	EMPLOYEES
. LAND AREA	500	ACRES
. EQUIPMENT	8,400	UNITS ($300 MILLION REPLACEMENT)
. FACILITIES		
TOTAL	79	BLDGS (30 DIRECT)
	4	DRYDOCKS (1 FLOATING)
	6	PIERS
DIRECT	40	WORK SITES
	1.32	MILLION SQ FT (SHOP SPACE)
. DIRECT WORK	16	SHOPS
	114	WORK CENTERS

WORK NON-STANDARDIZATION

1. SURFACE SHIPS

   FRIGATES, DESTROYERS, TENDERS, RESCUE VESSELS, BARGES, CRUISERS, ETC.

2. SUBMARINES

   DIESEL AND NUCLEAR BOTH SSN AND SSBN COMPRISING MANY DIFFERENT CLASSES IN EACH CATEGORY

3. TYPES OF WORK

   SRA, ERP, ROH, RAV, SOCC ETC.

4. SITES

   ANY OF THE SIX PIERS, FOUR DOCKS OR REMOTE AREAS

5. DURATION

   THREE WEEKS TO EIGHTEEN MONTHS

6. CONSTRAINTS

   WEIGHTS & SIZES INVOLVED

   LIMITED PRODUCTION RUNS ON SMALL ITEMS

   SEVERE WEATHER (CORROSION-RAIN, ETC.)

7. REPEATABILITY

   LIMITED

INDUSTRIAL PROCESSES (EXAMPLES)

1.	BENDING	13.	CALIBRATION
2.	SHAPING	14.	TESTING
3.	PUNCHING	15.	COMPONENT REPAIR (ELECTRICAL ELECTRONIC)
4.	SHEARING	16.	PAINTING - COATING
5.	SAWING	17.	BLASTING
6.	DRILLING	18.	CLEANING (ALL TYPES)
7.	WELDING	19.	INSULATION (ALL TYPES)
8.	CUTTING (FLAME)	20.	PLASTICS MANUFACTURE
9.	ELECTROPLATING	21.	RIGGING
10.	MACHINING	22.	PATTERN MAKING
11.	BALANCING	23.	CASTING
12.	HEAT TREATING	24.	FORGING

W - WATERFRONT S - INSIDE SHOP

SHOP, WORKCENTER AND WORK CENTER LOCATION LISTING

WC	W/S	DESCRIPTION
		CENTRAL TOOL SHOP
10	W	MACHINIST
11	S	ELECTRICIAN
12.	S	OFFICE MACHINERY
14.	S	TOOL ROOM MECHANIC
15.	W	NUC SUPPORT SYSTEM
16.	S	POINT ACCT. CONTROL (PAC)
17.	S	A/C & HEATING REPAIR SEC
		SHIPFITTER SHOP
11.	S	LOFT
13.	S	INSIDE SHIPFITTER (SURFACE CRAFT)
14.	S	INSIDE SHIPFITTER (SUBMARINE)
17.	W	OUTSIDE SURFACE CRAFT
20.	W	NUCLEAR WORK
21.	W	OUTSIDE SUBMARINES
		SHEETMETAL SHOP
16.	S	LABEL PLT AND LOCK LAYOUT AND SKETCH VENTILATION GENERAL BENCH MACHINE
17.	W	OUTSIDE (SURFACE)
19.	W	OUTSIDE (SUBS)
20.	W	NUCLEAR WORK
		WELDING SHOP
17.	W	WELD FLAME CUTTING
18.	W/S	P-1 & P-2 PIPE WORK
19.	W	OUTSIDE SURFACE CRAFT
20.	W	NUCLEAR WORK
21.	W	OUTSIDE SUBMARINES
22.	S	GAS PLANT
		MACHINE SHOP (INSIDE)
10.	S	ALL NON-NUCLEAR WORK
15.	S	ELECTROPLATING
21.	S	GAGE FACILITY (NON-NUC)
22.	S	NUCLEAR WORK

WC	W/S	DESCRIPTION
		MACHINE SHOP (MARINE)
10.	W	AUTO COMBUSTION CTR (ACC)
11.	W	INSIDE & OUTSIDE DIESEL
12.	W	OUTSIDE ORDNANCE
13.	S	INSIDE ORDNANCE
14.	W	NUCLEAR REPAIR
15.	W	SURFACE CRAFT PROPULSION
16.	W	DRYDOCK
17.	W	SUBMARINE PROPULSION
18.	W	OPTICAL
19.	W	NUC REFUELING
20.	W	SUB ORDNANCE & SAIL
21.	W	SUBMARINE AUXILIARIES
		BOILER SHOP
10.	S	SHOP WORK
11.	W	OUTSIDE WORK
20.	W	NUCLEAR WORK
		ELECTRIC SHOP
10.	S	MOTOR
11.	W	TESTS
12.	S	INSTRUMENTS
13.	W	DEGAUSSING
14.	S	SWBD AND HEATING
15.	S	GYRO
16.	W/S	BATTERY BLDG. 58
18.	W	SHIP ELEC (SURFACE)
19.	W	SHIP ELEC (SUBS)
20.	W	NUCLEAR POWER
21.	S	CBL HGRS AND ENGRAVING
		PIPE SHOP
10.	S	COPPER SHOP
11.	S	INSIDE PIPE SHOP
12.	W	OUTSIDE PIPE SHOP
13.	W	WAVE GUIDE
14.	W	SHIPBD REF AND A/C
15.	W	PIPECVR AND INSLTR
16.	W	OUTSIDE NUCLEAR
17.	S	INSIDE NUCLEAR
18.	S	INSIDE REF & A/C
19.	W	SILVER BRAZING
20.	W	NUC PWR SYS TESTING AND FLUSHING
21.	W	NON-NUC SYS TEST/FLUSH
22.	W	NUC ACCOUNTABILITY SYSTEM

SHOP, WORKCENTER AND WORK CENTER LOCATION LISTING

WC	W/S	DESCRIPTION
		WOODWORKING SHOP
10.	S	SMALL BOAT
11.	S	SHOP
12.	W	SUB AND WOODEN HULL
13.	W	DRYDOCK SECTION
14.	S	MILL
15.	W	STEEL HULLS
16.	S	BLOCKING,SHORING & CRATING
17.	S	PATTERN
18.	S	NUCLEAR WORK
19.	W	DRYDOCK SECTION(NUCLEAR)
		ELECTRONICS SHOP
10.	W	SHIP ELEX (SUBS)
11.	S	OPTICAL
13.	S	TRANS HYDROSTATIC TEST & ENCAPSULATION
14.	W	FIRE CONTROL
16.	S	RADIAC
17.	S	TELETYPE
19.	S	ANTENNA
20.	S	INTERNAL SECURITY
21.	S	TEST EQUIP & INSTR. RPR
22.	S	CRF
24.	S	TEST EQUIP & INSTR CALIB

WC	W/S	DESCRIPTION
		MODULE MAINTENANCE
10.	S	MOD INSP & TESTING
11.	S	MOD RPRS & MODS
12.	S	TECH SUPPLY SUPPORT
		PAINT SHOP
10.	W	SHIPBOARD
11.	S	SHOP
12.	W	DRYDOCK
13.	W	SANDBLASTING
14.	W	NUCLEAR WORK
15.	W	LABORER (SUBMARINES)
16.	W	LABORER (SURFACE SHIPS)
		RIGGER SHOP
10.	S	MFGING
11.	W	TEST
12.	W	OUTSIDE RIGGERS
13.	W	DIVING
14.	W	SOUND SRVY
15.	W	LABORERS (SUB)
16.	W	LABORERS (TANK CLEANERS)
17.	W	LABORERS (SURF)
18.	W	SAIL LOFT
19.	W	NUC RIGGERS
20.	W	COMPONENT CLEANER
		TEMPORARY SERVICES SHOP
10.	W	PIPEFITTER
11.	W	ELECTRICIANS
12.	S	NUC. FAC

CANDIDATE PROCESSES

1. SUBMARINE BATTERY MANUFACTURE
2. ELECTRONIC GROUP
3. PROPELLER REPAIR
4. TANK CLEANING
5. BLASTING - PAINTING

SHIPYARD PROCESSES AND PROCESS ANALYSES.

HISTORICAL BACKGROUND OF LONG BEACH NAVAL SHIPYARD

BY: LOUIS SMITH

The Long Beach Naval Shipyard is located on Terminal Island between the cities of Long Beach and San Pedro, California. The Shipyard, one of eight Naval Shipyards in the U.S., first known as the U.S. Naval Drydocks, Terminal Island, was established in 1940. Initial funding was $19 million for dredging, land and construction of facilities. Construction was actually started in November 1940 and the first major ship was drydocked in September 1942. Originally it was planned for the Shipyard to be operated by a private company, Bethlehem Steel Corporation. This was changed in February 1943 and the Navy began action to staff and operate the Shipyard. Construction of facilities continued and by 1943 it went into full production for the repair, overhaul and conversion of the ships of the Pacific Fleet.

Today the Shipyard has three graving docks, four industrial piers, two wharfs and extensive shop and office complexes and is one of the Navy's most modern shipyards. Recent construction of the Electrical/Electronic/Weapons Facility, Engineering/ Management Building, Service Group Building and the Pipe and Copper Shop are a continuing part of the Shipyard Modernization Program.

Among the Shipyard's landmark features are the giant Moreell Drydock and the YD-171 crane. The Moreell Drydock has a 56,000,000 gallon capacity and can drydock most of the Navy's largest ships, exception being NIMITZ-class carriers. Official authorized drydock tonnage capacity is 58,500 long tons. The YD-171 is one of the world's largest self-propelled floating cranes. It is 374 feet high with a lifting capacity of 386 tons.

The Shipyard's first employee was hired in March, 1943. Employment reached a high of 16,091 in August 1945. The work force level has remained fairly stable over the operating years between 7,000 to 8,000 people. There are about 120 crafts and skills organized in 16 production shops with a variety of supporting engineers, managers, administrators, technicians and building maintenance personnel. The Shipyard is organized into 14 Departments/Offices with four Production Department Shop Groups and one Public Works Shop Group. The Shipyard is a major industry in the local area. It is estimated that the Yard will do in excess of $368,000,000 worth of work in FY83.

Through the years this Shipyard has accomplished several special projects in addition to its primary mission. These include support of scientific projects in conjunction with programs like

POLARIS, PC E. ON, and SEALAB. Currently the Shipyard operates electronic and weapons checkout and evaluation functions.

The Long Beach Naval Shipyard is equipped with facilities and skills capable of performing all structural, sheetmetal, boiler, rigging, electronics, electrical, lagging, ordnance, sandblasting, welding, machining, woodworking, painting, pipefitting and other work incidental to the overhaul and repair of surface ships. The Shipyard possesses complete design, engineering, and planning capabilities to support its industrial work. The workload of this Shipyard consists largely of overhaul and maintenance of s rf e ships.

Long Beach Naval Shipyard

High Labor Processes

Process	Shop	Touch Labor Hrs/Yr (K)	Total Cost/Yr ($K)	Hazardous/ Unpleasant Work Environment	Labor Skill Required	Job Training	Key ops Common to Other Processes
(Ship) Welding	26	628	10007	Y	M-H	4 yr	
(Ship) Pipe-fitting	56	602	18680	Y	H	4 yr	Y
(Ship) Elec-tricians	51	469	15167	N	H	4 yr	Y
Main&Aux Prop. Repair	38	395	1104	Y	H	4 yr	Y
Rigging	72	385	5356	Y	H	4 yr	
Blasting	71	304	4246	Y	L	OJT	N
Painting	71	252	3518	Y	M	4 yr	N
DD Ship-wrights	64	221	3347	Y	H	4 yr	Y
Ship-fitting Assy.	11	220	3513	Y	Y	2 yr	
Machining	31	218	7194	N	M	4 yr	Y

Long Beach Naval Shipyard

High Labor Processes

Process	Shop	Touch Labor Hrs/Yr (K)	Total Cost/Yr ($K)	Hazardous/ Unpleasant Work Environment	Labor Skill Required	Job Training	Key ops Common to Other Processes
(Ship) Pipe-fitting	56	602	18680	Y	H	4 yr	Y
(Ship) Elec-tricians	51	469	15167	N	H	4 yr	Y
(Ship) Welding	26	628	10007	Y	M-H	4 yr	
Diesel Repair	38	32	8966	Y	H	4 yr	
Govenor Rebuild	38	32	7846	N	H	4 yr	
Air Comp Rebuild	38	28	7285	Y	H	4 yr	
General Machining	31	218	7194	N	M	4 yr	Y
(Ship) Elex Repair	67	162	5715	N	M-H	4 yr	Y
Valve Repair	31	166	5478	N	M	4 yr	Y
Rigging	72	385	5356	Y	H	4 yr	

SHOP 11

SHIPFITTERS

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(106) Assembly	220.5	3,512.6	Yes	High	2 Yr APP	No	Yes
(14) Disassembly	29.1	463.6	Yes	High	2 Yr APP	No	Yes
(14) Material Movement	29.1	463.6	No	Low	1 Yr APP	Yes	No
(29) Material Handling	60.3	960.6	No	Low	1 Yr APP	Yes	No
(86) Cutting & Forming	178.9	2,849.9	Yes	Mod	2 Yr APP	Yes	Yes
(3) Deburring	6.2	98.8	No	Low	1 Yr APP	Yes	No
(6) Burning	12.4	197.5	Yes	High	1 Yr APP	Yes	Yes
(29) Lofting/Layout	60.3	960.6	No	High	4 Yr APP	Yes	Yes
TOTALS	596.8	9,507.2					

*Composite Labor Rate $15.93/Hr

SHOP 17

SHEETMETAL WORKERS

PROCESS	TOUGH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISIO REQUIRED
(41) Metal Forming	85.3K	1,358.8	No	Mod-High	1 Yr APPR	NO	Yes
(6) Matr'l Handling	12.5	199.1	No	Low-Mod	6 Mth OJT	Yes	No
(3) Parts Cleaning	6.2K	98.8	Yes	Low-Mod	1 Yr OJT	Yes	No
(6) Deburring/Finishing	12.5K	199.1	Yes	Low/Mod	1 Yr OJT	Yes	Yes
(6) Matr'l Storage	12.5K	199.1	No	Low/Mod	6 Mth OJT	Yes	No
(38) Assembly	79.0	1,258.5	No	High	2 Yr APPR 3 Yr OJT	No	Yes
(16) Sketch Rm	33.3	530.5	No	High	4 Yr APPR	No	Yes
TOTALS	241.3	3,843.9					

*Composite Labor Rate $15.93/Hr

SHOP 26

WELDERS

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(302) Welders	628.2	10,00Ø7.2	Yes	Mod-High	4 Yr APPR	Yes	Yes
(10) Burners	20.8	331.3	Yes	Low-Mod High	1 Yr OJT 2 Yr APPR	Yes	Yes
(1) Flame Spray	2.08	33.1	Yes	High	4 Yr OJT	No	Yes
(5) Plasma Spray	10.4	165.7	Yes	High	4 Yr OJT	No	Yes
TOTALS	661.48	10,537.3					

*Composite Labor Rate $15.93/Hr

SHOP 41

BOILERMAKERS, BLACKSMITHS, HEATTREAT'S FOUNDRY

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
Boilermakers							
(70) Test/Installation	145.6K	2,319.4K	Yes	Mod-High	4 Yr APPR 4 Yr OJT	No	Yes
(26) Removal/Disassembly	54.1K	861.8	Yes	Low-Mod	6 Mth OJT	Yes	No
(17) Matr'l Handling	35.4	563.9	No	Low	6 Mth OJT	Yes	No
Material (44) Cutting/Forming	91.5K	1,457.6	No	Mod-High	2 Yr APPR 2 Yr OJT	No	Yes
(18) Layout	37.4K	595.8	No	High	4 Yr APPR 4 Yr OJT	No	Yes
(11) Blacksmith							
Forge-Consumable							
Rings/Springs	22.9K	364.8	Yes	Mod-High	2 Yr APPR 4 Yr APPR	No	Yes
(5) Heattreaters							
Heattreat/Test	10.4K	165.7	No	Mod-High	3 Yr OJT 2 Yr APPR	No	Yes
(11) Foundry							
Molders							
Finishing/Deburring	22.9K	364.8	Yes	Low-Mod High	6 Mth OJT	Yes	Yes
TOTALS	420.2	6,693.8					

*Composite Labor Rate $15.93/Hr

SHOP 31

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k)	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn's common to other processes
1 General Machining	218	7194	NO	MEDIUM	4 yr. app	YES
2 Valve Repair	166	5478	NO	MEDIUM	4 yr. app	YES
3 Pump Repair	132	4356	Testing	MEDIUM	4 yr. app	YES
4 Tool Making Tool Grinding	62	2046	Grind dust	HIGH MEDIUM	6 yr. app 1 yr. OJT	NO
5 NC Machining	48	1584	No	MEDIUM	4 yr. app. plus 1 yr OJT	YES
6 Precision Grinding	40	1320	No	HIGH	4 yr. app	YES
7 Production Machining	38	1254	No.	MEDIUM	4 yr. app	YES
8 Balancing	24	792	Grind Dust	HIGH	4 yr. app	YES
9 NC Program	20	660	NO	V. HIGH	4 yr. app 2 yr. OJT	NO
10 Gen. Assy. & Display	18	594	NO	MEDIUM	4 yr. app	YES
11 Babbitting	16	528	Not work	HIGH	4 yr. app	YES
TOTALS	782	25,806				

SHOP 38

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k)	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn's common to other processes
1 Main & Aux. Rep	395	1104	Heat, fumes dirty	V. HIGH	4 yr. app	
2 Refrigeration: Rebuild	48	1340	Gas	V. HIGH	4 yr. app	
3 SHT Rebuild	40	1120	Fumes, oil	HIGH	4 yr. app	
4 Combustion Control	36	1008	Heat	HIGH	4 yr. app	
5 Hydraulic Repair	36	1008	Toxic Fumes	V. HIGH	4 yr. app	
6 Diesel Repair	32	8966	Fumes Oil	HIGH	4 yr. app	
7 Gov. Rebuild	28	7846	No	HIGH	4 yr. app	
8 Air Comp. Repair	26	7285	Noise Oil	HIGH	4 yr. app	
9 Component Repair	10	28	No	Mod High	4 yr. app	
TOTAL	651	28499				

SHOP 56

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k) $31.01/hr	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn's common to other processes
1 Pipefitters, Shop-Ferreous	50.2	1556.7	YES	HIGH	4 yr. app	YES
2 Pipefitters, Shop-Nonferr	40.2	1246.6	YES	HIGH	4 yr. app	YES
3 Waveguide Remy-Fab-Inst	28.1	871.4	YES	HIGH	6 yr. trng'	YES
4 Boring	24.1	747.3	YES	HIGH	5 yr. trng'	YES
5 Pipefitters, Field	602.4	18680.4	YES	HIGH	4 yr. app	YES
6 Dry Air Radar Cooling	70.3	2180.0	No	HIGH	6 yr. trng'	YES
7 Coolers	44.2	1370.6	No	HIGH	5 yr. trng'	YES
SHOP 57		$30.48/hr				
Insulators, Shop	20.0	612.6	NO	Mod-High	4 yr. app	NO
Insulators, Field	261.0	7955.3	YES	Mod-High	4 yr. app	YES

SHOP 36

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k)	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn' commo other proce
1 WPNS (Shop) Mech/Hyd.	12	398	NO	HIGH MEDIUM	4 yr. app	YES
2 WPNS (Ship) Mech/Hyd.	113	3,696	NO	HIGH MEDIUM	4 yr. app	YES
3 Weapons Repair	117	3,310	NO	HIGH	4 yr. app	YES
4 Naval Optical	15	511	NO	HIGH	4 yr. app	NO
TOTALS	257	8,415				

SHOP 66

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k) $31.01/hr	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn' commo other proce
1 Antenna, Restoration, and Repair	26.2	662.6	NO	HIGH	4 yr. appt. and OJT	YES
2 Test Equip. Restoration & Repair	31.5	796.6	NO	VERY HIGH	4 yr. appt. and OJT	YES
3 Electronic System Repair	80.5	2,035.8	NO	HIGH	4 yr. appt.	YES
TOTALS	138.2	3,495				

SHOP 51

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k)	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn' commc other proce
1 Rotating Assembly Repair	42.0	1358	NO	HIGH MEDIUM	4 yr. app	YE:
2 Processing Engraving	24.0	792	Chemical bath & fumes	HIGH MEDIUM	OJT	NO
3 Connector Plug/Fab.	38.5	1,245	NO	MEDIUM HIGH	OJT	NO
4 Electronic Systems Repair	152.3	4,925	NO	HIGH	4 yr. app	YE
5 PLATING	12.3	398	Chemical bath & fumes	HIGH	OJT	YE
6 Chem. Clng Film Coat	31.6	1,019	Chemical bath & fumes	MEDIUM	OJT	YE
7 Field Electronics	469.0	15,167	NO	HIGH	4 yr. appt	YE
TOTALS	770.1	24,904				

SHOP 67

Process	Touch Labor Hrs/yr (k)	Total cost/yr (k)	Hazardous Unpleasant Work Event	Labor Skill Required	Job training	kopn' commo other proce
1 Electronic Shipboard Sys. Repair	162.4	5,715	NO	MEDIUM HIGH	4 yr. app	YES
2 Elec/Elex Test Equip. Calibration	126.0	4,433	NO	VERY HIGH	4 yr. app	YES
3 Waveguide/ Antenna Repair/Instal	19.6	690	NO	VERY HIGH	4 yr. app	NO
TOTAL	308.0	10,838				

SHOP 64

WOODWORKING SHOP

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(5) Boat Repair	10.4	157.9	Yes	High	4 Yr APP	No	Yes
(8) Mill & Joiner	16.6	252.0	Yes	High	4 Yr APP	No	Yes
(5) Scaffold/Staging	10.4	157.9	No	Mod	2 Yr OJT	Yes	No
(106) DD Shipwrights	220.5	3,347.2	Yes	High	4 Yr APP	No	Yes
(21) Plastics Shop	43.7	663.4	Yes	High	4 Yr APP	No	Yes
(8) Pattern Shop	16.6	252.0	No	High	4 Yr APP	No	Yes
TOTALS	318.2	4,830.4					

*Composite Labor Rate = $15.18/Hr

SHOP 71

PAINT & BLAST SHOP

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(121) Painting	251.7	3,518.8	Yes	Mod	4 Yr APP	Sometimes	Sometime
(146) Blasting	303.7	4,245.7	Yes	Low	OJT	Yes	No
TOTALS	555.4	7,764.5					

*Composite Labor Rate = $13.98/Hr

SHOP 72

RIGGING SHOP

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(185) Rigging	384.8	5,356.4	Yes	High	[illegible] Yr APP	No	Yes
(10) Sail Loft	20.8	289.5	No	High	4 Yr APP	No	Yes
(8) Divers	16.8	231.1	Yes	High	4 Yr APP	No	Yes
TOTALS	422.4	5,877.0					

*Composite Labor Rate = $13.92/Hr

LONG BEACH NAVAL SHIPYARD

Aluminum Modular Ships Berthing Bunks

Exploded views of several styles

By: Les Hartzell

1. Three pan berth.

2. Two locker, one pan.

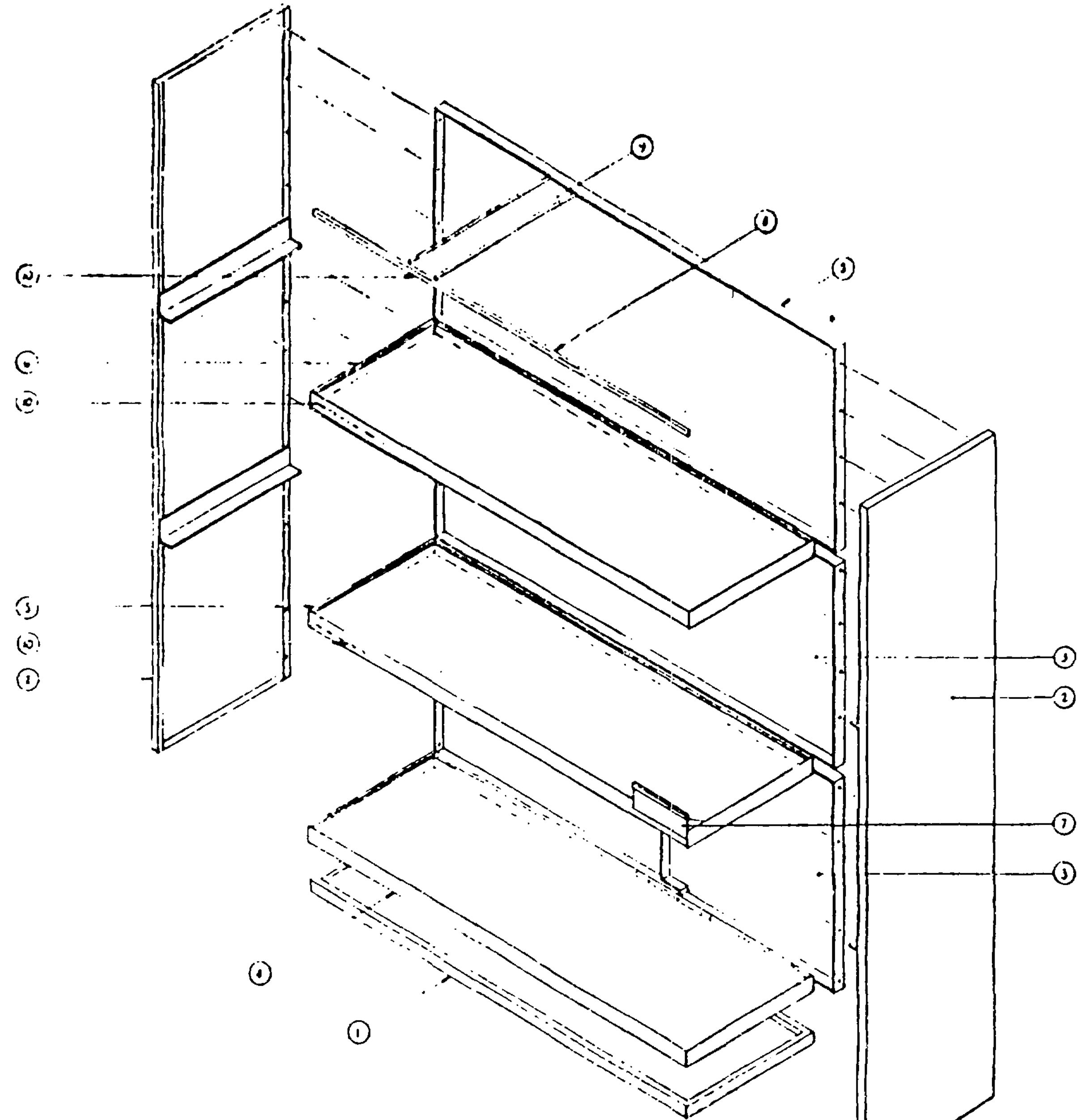
3. Two locker berth.

4. Three locker berth.

5. Completely assembled three locker berthing bunks.

6. Composite robotic spot welder with locker bunk holding fixture.

7. Composite robotic spray painter spraying locker bunk.

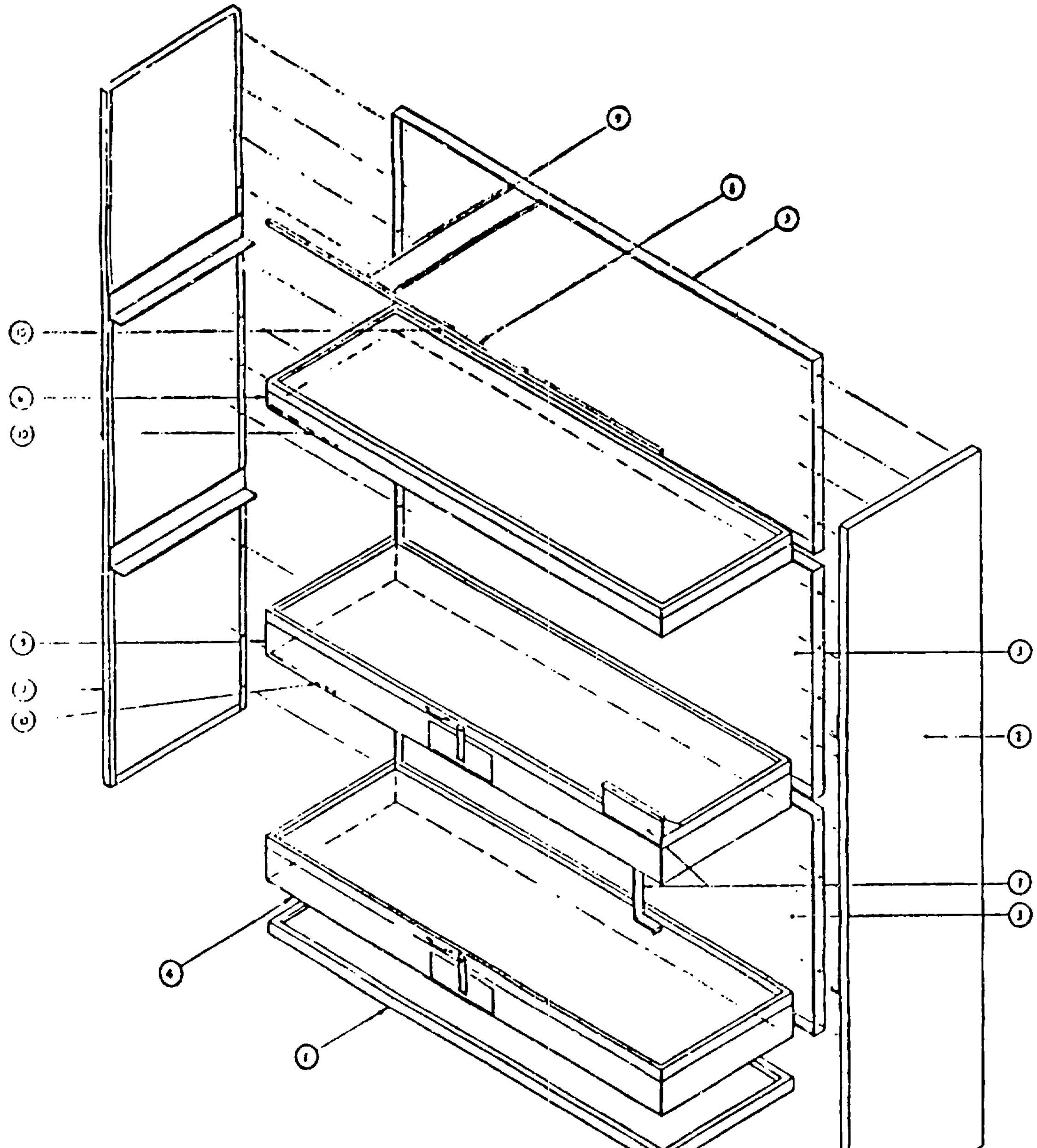


THREE PAN BERTH — LEFT HAND

NOTE

1. ASSEMBLE BUNK STARTING WITH [illegible] FIRST THRU [illegible]
2. HARDWARE REQUIRED TO ASSEMBLE BUNKS ARE [illegible] BOLTS AND NUTS AND [illegible] ALUMINUM POP RIVETS

PART	DESCRIPTION	MAT'L
1	FOUNDATION	STL
2	SIDE PANELS	AL
3	BACK PANEL	AL
4	PAN BERTH	AL
5	PAN BERTH	AL
6	PAN BERTH	[illegible]
7	STEPS	AL
8	TUBING [illegible]	AL
9	LIGHT PLATE	AL
10	CURTAIN TRACK	AL

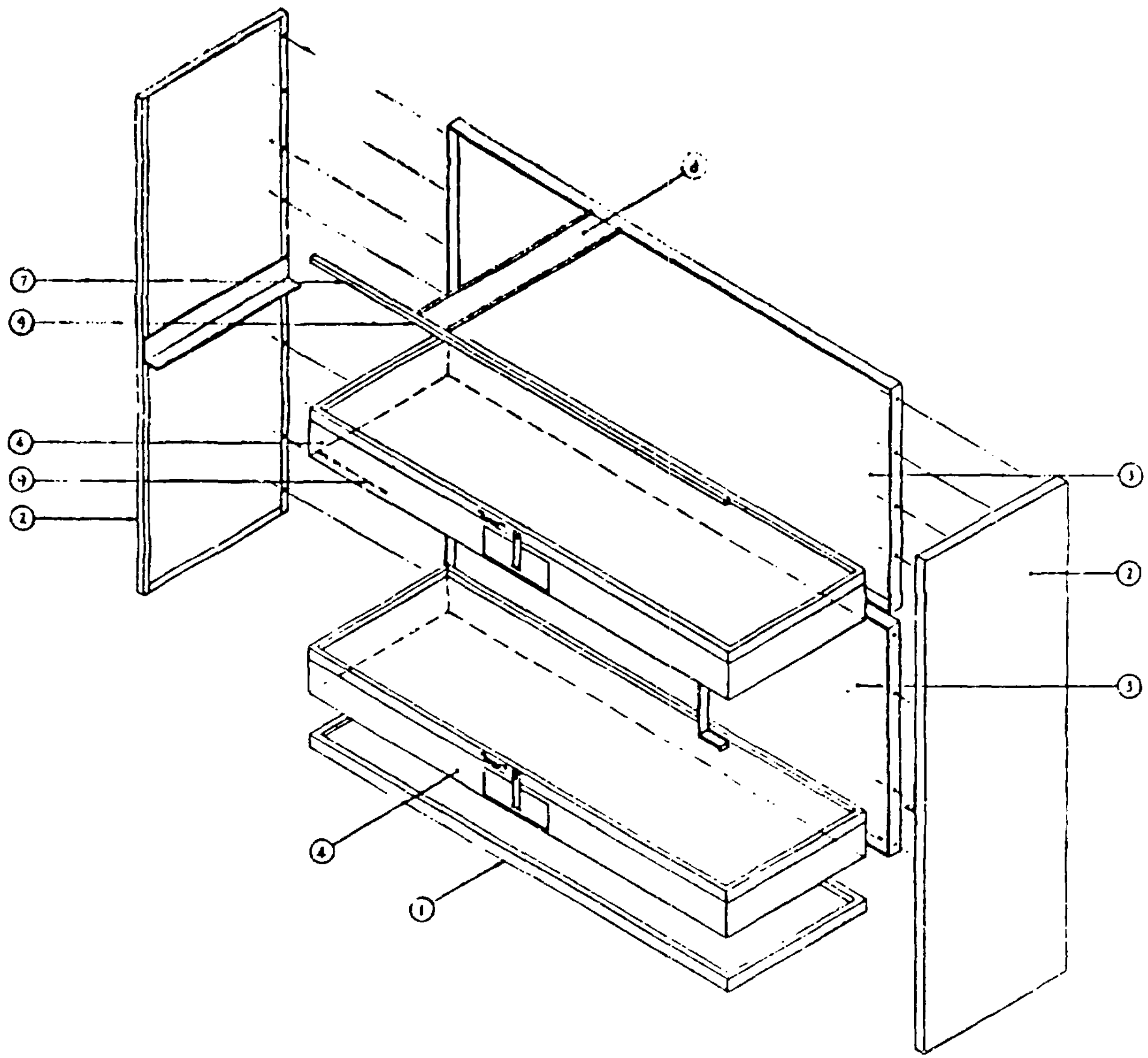


TWO LOCKER, ONE PAN — LEFT HAND

NOTE:

1. ASSEMBLE BUNK STARTING WITH PC NO 1 FIRST THROUGH PC NO 10
2. HARDWARE REQUIRED TO ASSEMBLE BUNKS; 1/8" x 1" BOLTS AND NUTS, AND 1/4" ALUMINUM POP RIVETS

PC NO	DESCRIPTION	MAT'L
1	FOUNDATION	STL
2	SIDE PANELS	AL
3	BACK PANEL	AL
4	BERTH LOCKER	AL
5	BERTH LOCKER	AL
6	BERTH PAN	AL
7	STEPS	AL
8	TUBING 1" x 1"	AL
9	LIGHT PLATE	AL
10	CURTAIN TRACK	AL



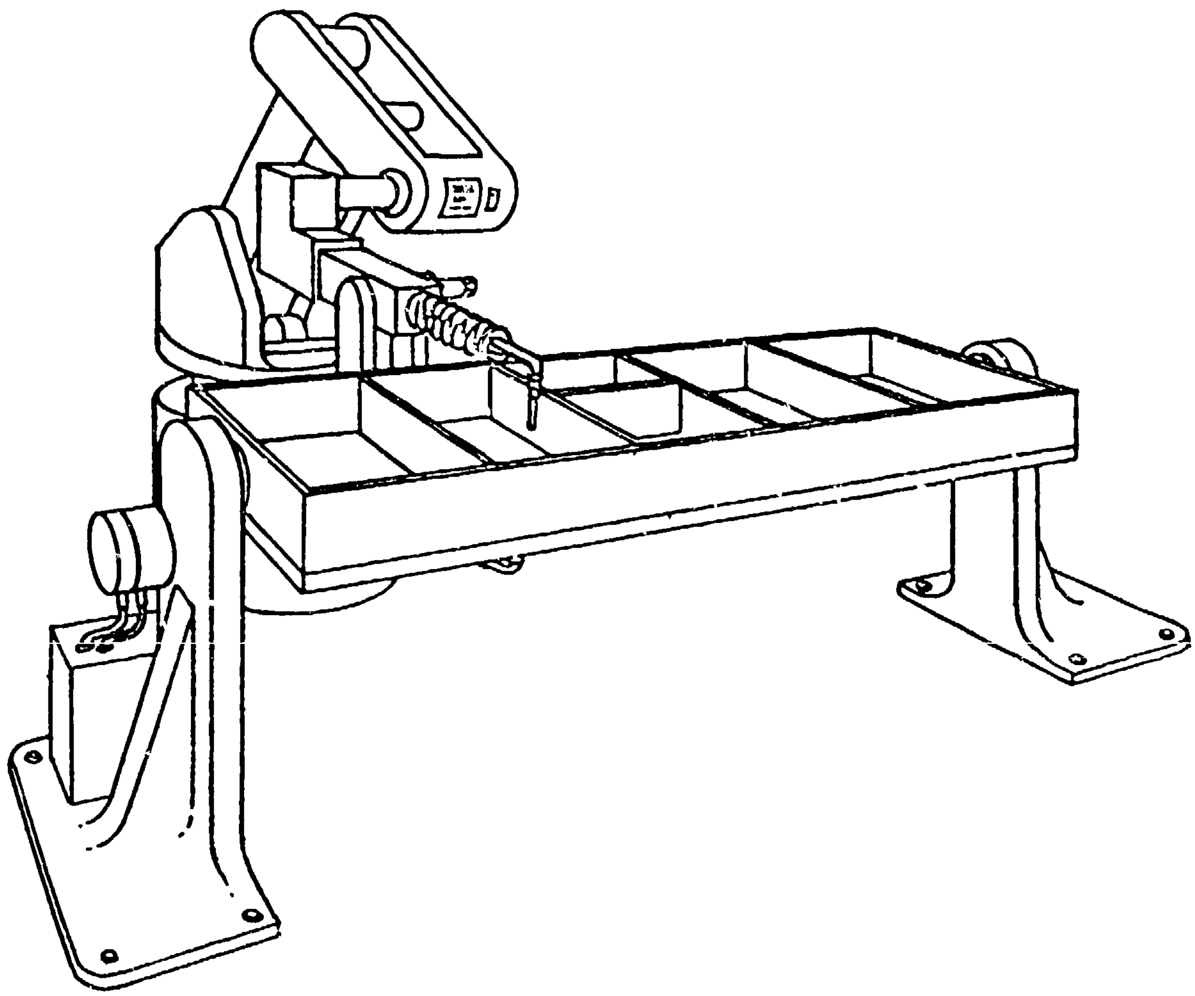
NOTE

1. ASSEMBLE BUNK [illegible] WITH PC NO 1 FIRST TH[illegible]

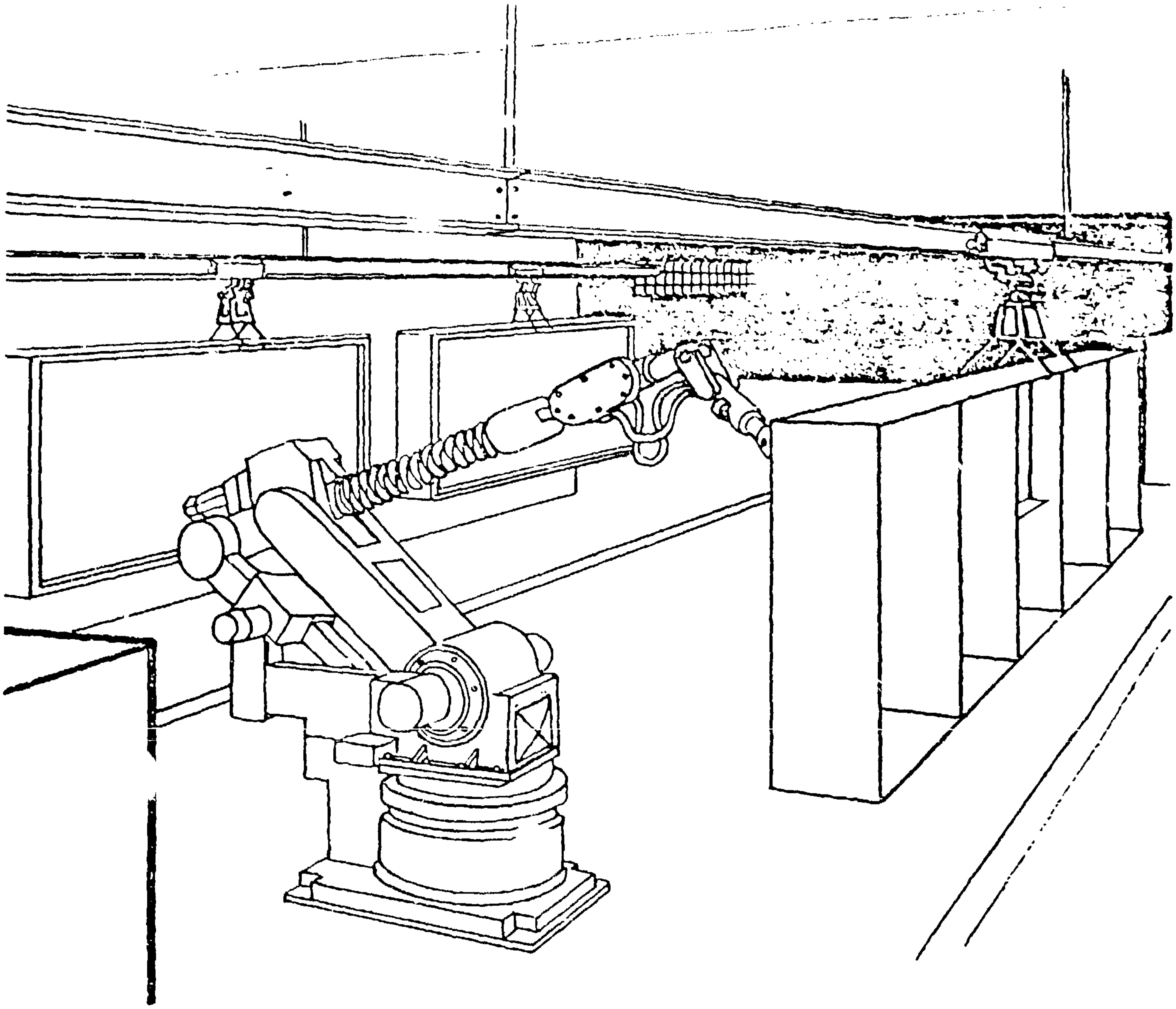
2. HARDWARE REQ[illegible] ASSEMBLE BUNKS ARE AS[illegible] [illegible] AND 1/4" ALUMIN[illegible] [illegible] RIVETS

PC NO	DESCRIPTI[illegible]	[illegible]	MAT L
1	FOUNDATIO[illegible]		[illegible]
2	SIDE PANEL[illegible]		AL
3	BACK PANEL[illegible]		AL
4	BERTH LO[illegible]		AL
5	BERTH LOC[illegible]		AL
6	STEPS		AL
7	TUBING [illegible]		AL
8	LIGHT PLATE		AL
9	CURTAIN TR[illegible]		AL

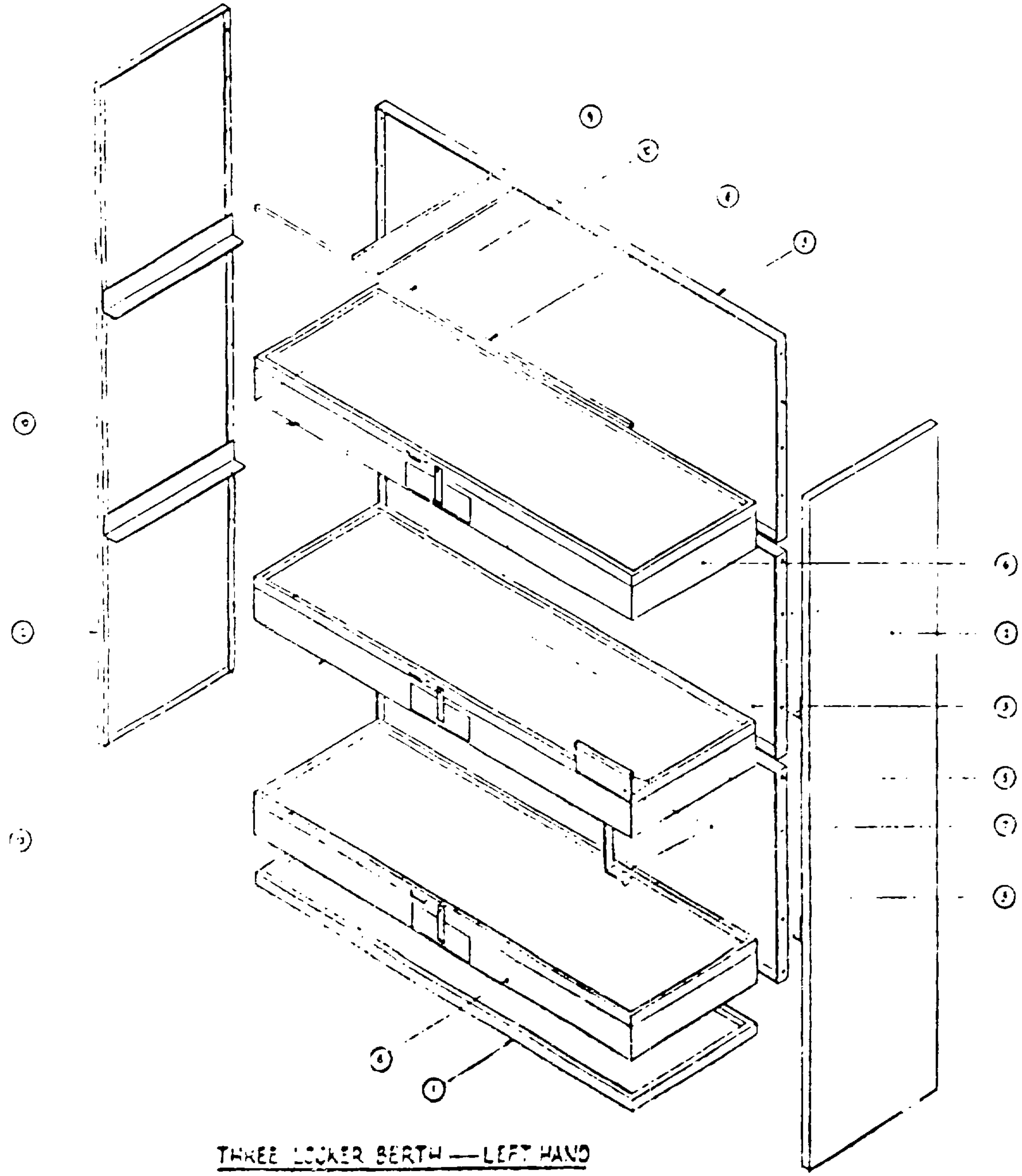
TWO LOCKER BERTH — LEFT HAND



ROBOTIC SPOTWELDER



ROBOTIC SPRAY PAINTER



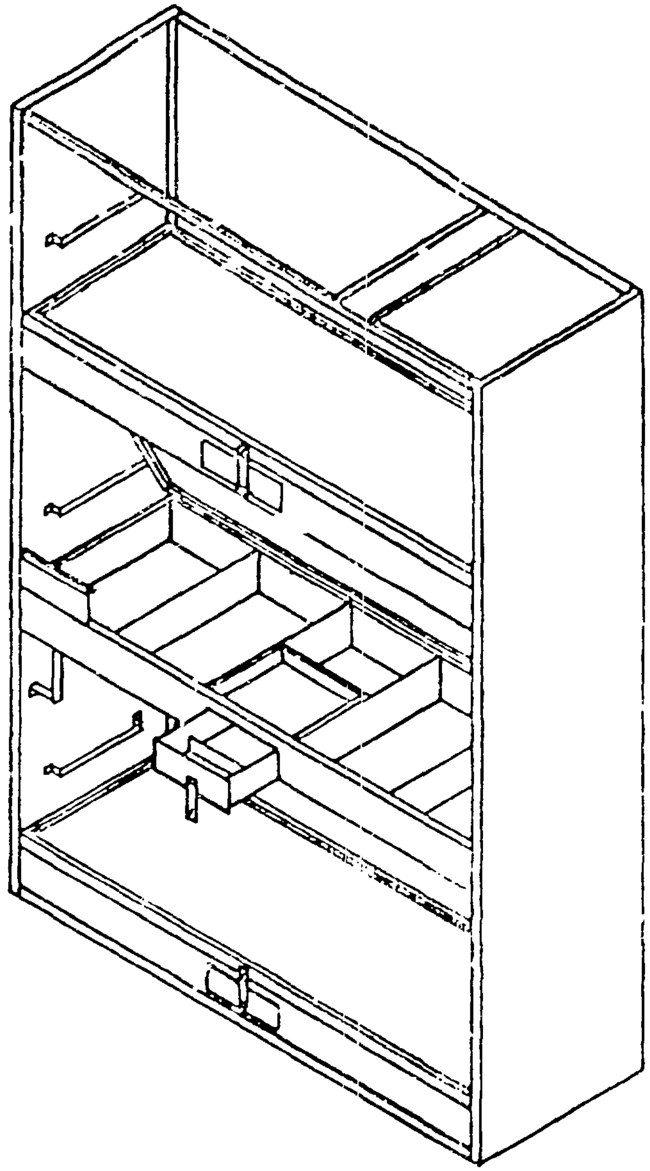
THREE LOCKER BERTH — LEFT HAND

NOTES:

[illegible]

NO.	DESCRIPTION	QTY.
1	BOUNDARY [illegible]	[illegible]
2	SIDE PANELS	[illegible]
3	BACK PANELS	[illegible]
4	BERTH LOCKER	[illegible]
5	BERTH LOCKER	[illegible]
6	BERTH LOCKER	[illegible]
7	STEPS	[illegible]
8	TUBING [illegible]	[illegible]
9	LIGHT PLATE	[illegible]
10	CURTAIN TRACK	[illegible]

LONG BEACH NAVAL SHIPYARD

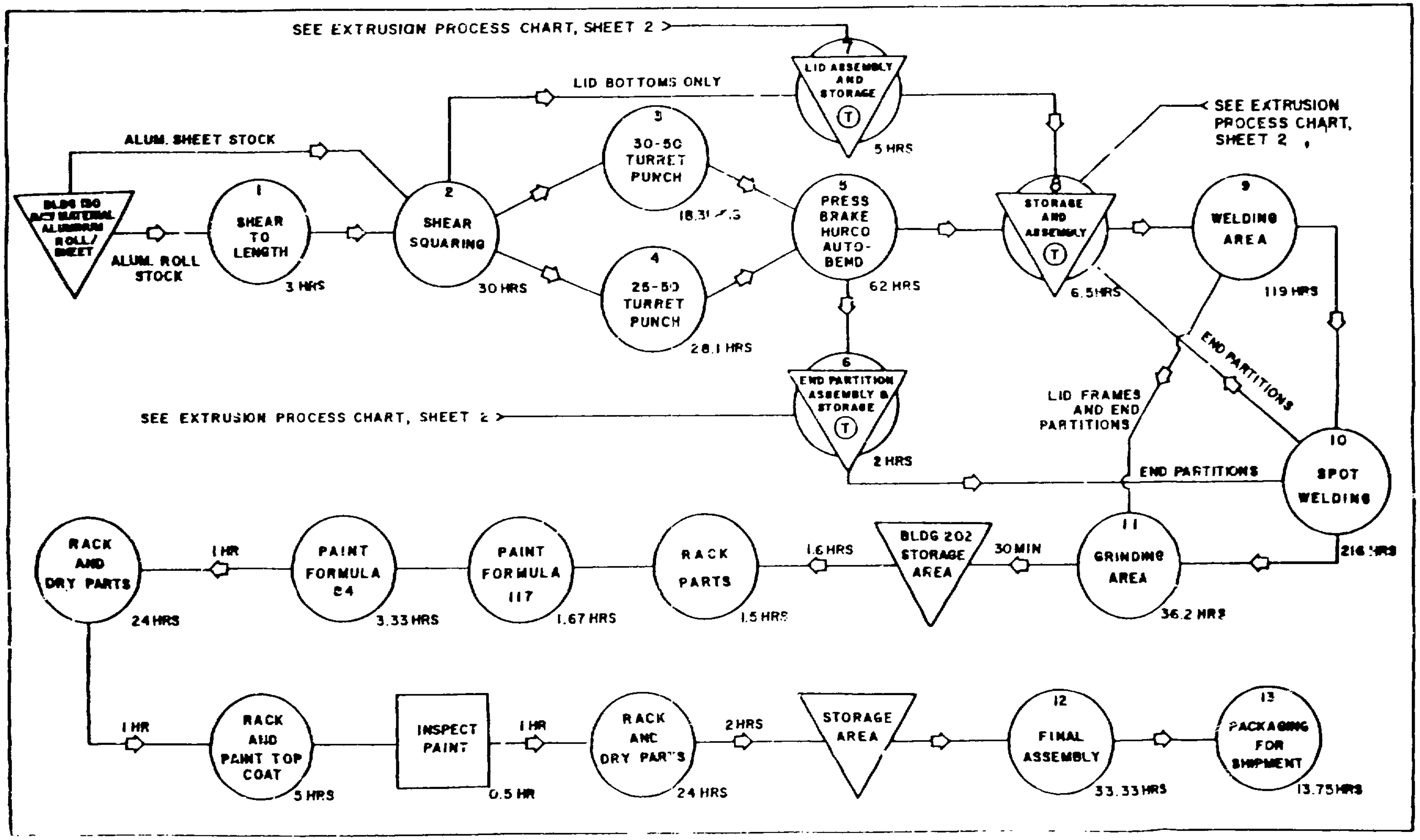


MODULAR BERTHING

NOTE: TIMES BASED ON 35 TIERS
3 LOCKER-TYPE BERTHS/TIER
(100 BERTHS FOR SIMPLICITY)

LONG BEACH NAVAL SHIPYARD
MODULAR BERTHING PROCESS CHART FOR SHEETMETAL FABRICATION

DRAWING SS 2157
SHEET 1 OF 3



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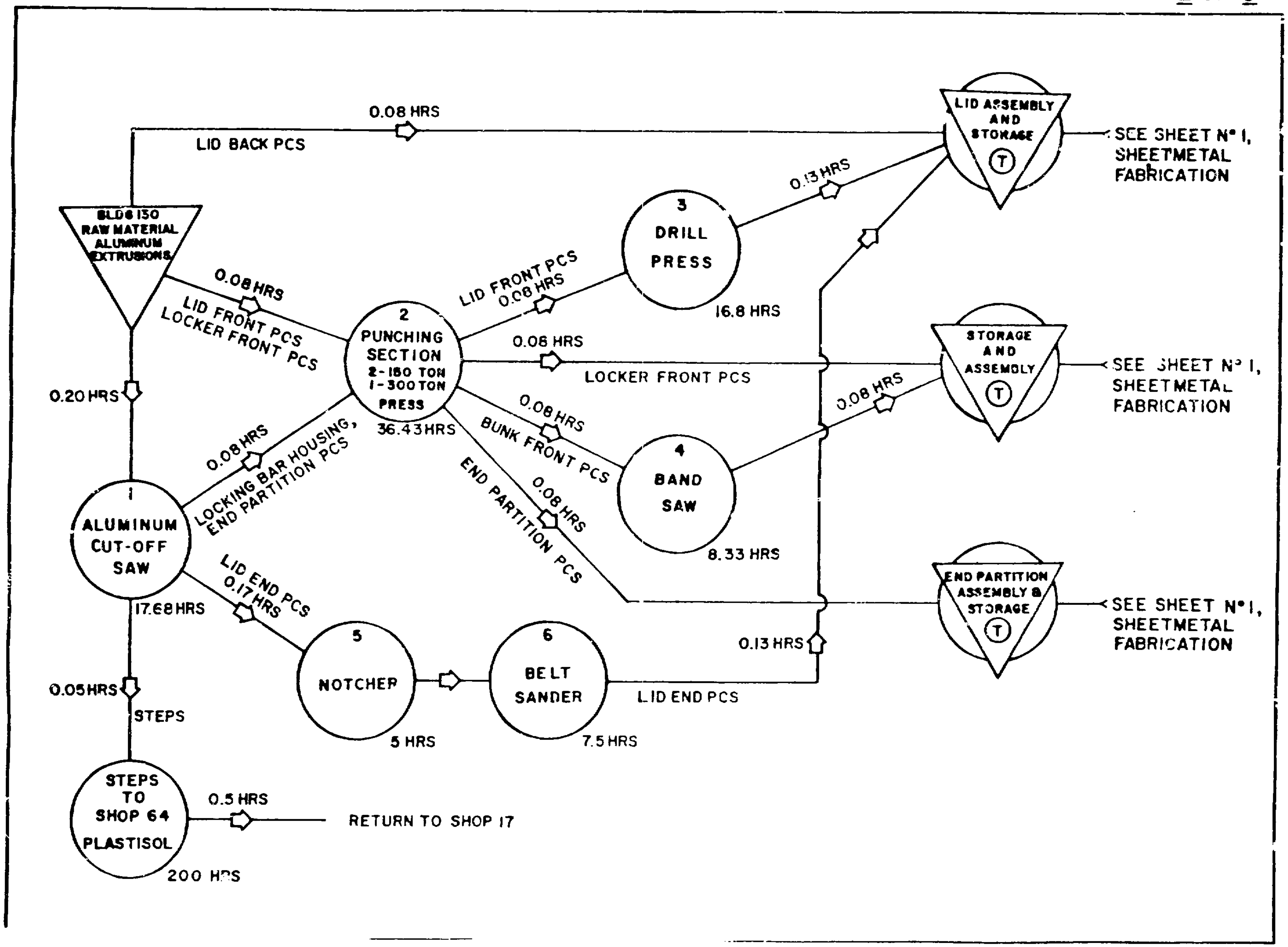
NOTE: EXTRUSION TIMES
BASED ON 500 PCS

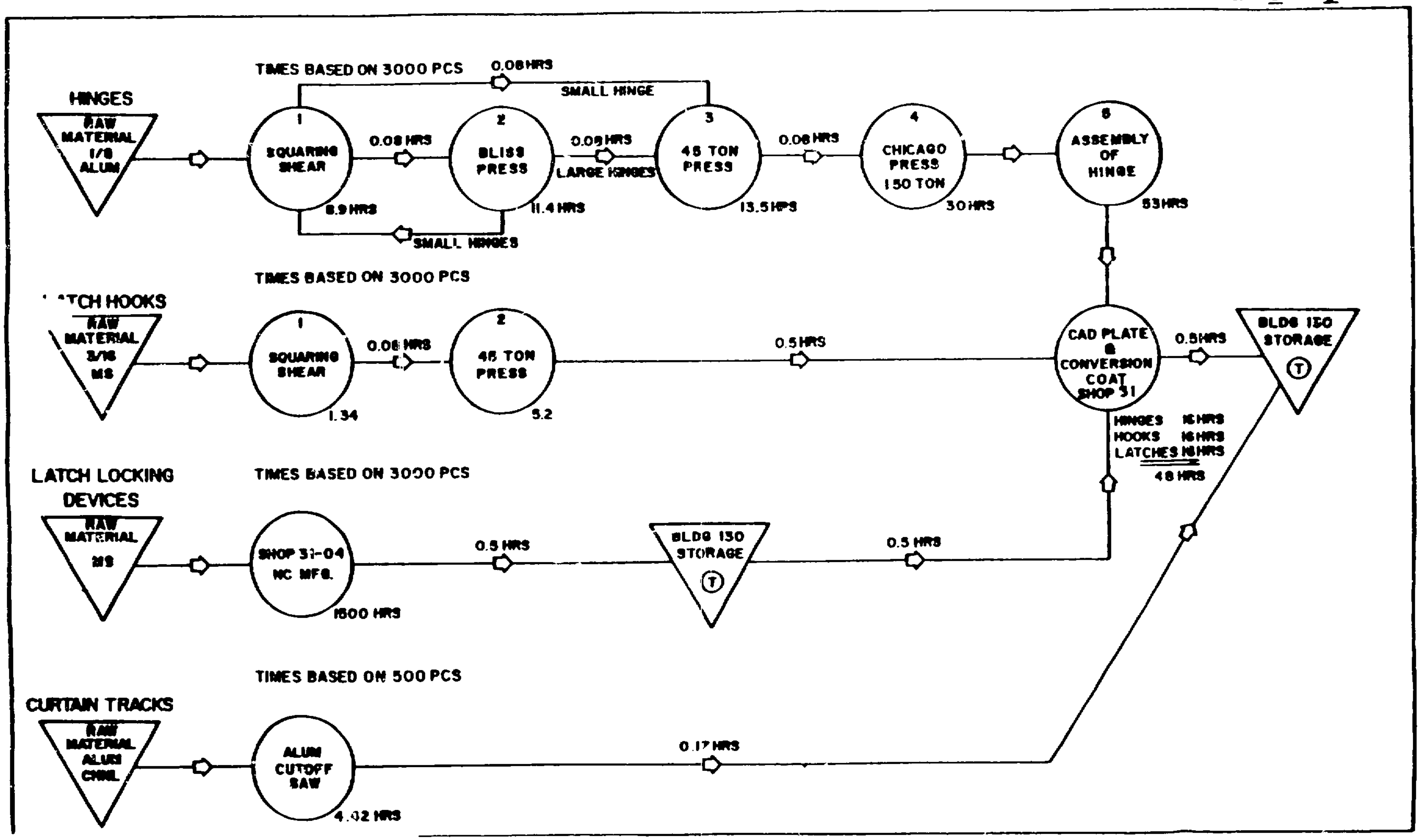
LONG BEACH NAVAL SHIPYARD
MODULAR BERTHING PROCESS CHART
FOR ALUMINUM EXTRUSION FABRICATION

DRAWING SS 2157
SHEET 2 OF 3



LONG BEACH NAVAL SHIPYARD
MODULAR BERTHING PROCESS CHART
FOR HARDWARE FABRICATION

DRAWING SS2157
SHEET 3 OF 3



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200

ALUMINUM MODULAR SHIPS BERTHING BUNKS

SHOP 17

SHEETMETAL SHOP

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
(12) Metal Cutting Punching & Forming	12.791	203.761	No	High	3rd year Appr. to Journeyman	No	Yes
(2) Welding	9.339	148.770	Yes	High	3rd year Appr. to Journeyman	No	No
(4) Spot Welding	16.952	270.045	No	Set Up Mod to High, Oper. Mod to Low	1st year Appr & OJT	Yes	No
(2) Grinding	2.841	45.257	Yes	Low	OJT	Yes	No
(3) Material Movement	.254	4.046	No	Low	OJT	No	No
(2) Plating	.126	2.007	Yes	High to Mod	3rd year Appr.to Journeyman	No	No
(3) Assembly	3.815	60.773	No	Mod	1st year Appr. & OJT	No	No
(2) Packaging	1.079	17.188	No	Low	1st year Appr. & OJT	No	No
TOTALS	47.197	751.847					

*Composite Labor Rate $15.93/Hr

ALUMINUM MODULAR SHIPS BERTHING BUNKS

SHOP 71

PAINT SHOP

PROCESS	TOUCH LABOR HRS YR(K)	*TOTAL COST YR(K)	HAZARDOUS UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	BORING REPETIVE	PRECISION REQUIRED
Paint (2) #117, #84 & Beige							
Side Panels	0.680	9.506	Yes	Yes	4 Yr App	Yes	Yes
Back Panels	1.020	14.260	Yes	Yes	4 Yr App	Yes	Yes
Bunk Lids	1.020	14.260	Yes	Yes	4 Yr App	Yes	Yes
Bunk Lockers	1.020	14.260	Yes	Yes	4 Yr App	Yes	Yes
Bunk Fnds	0.078	1.090	Yes	Yes	4 Yr App	Yes	Yes
Move (2)							
Side Panels	0.419	5.858	No	No	No	Yes	No
Back Panels	0.628	8.779	No	No	No	Yes	No
Bunk Lids	0.628	8.779	No	No	No	Yes	No
Bunk Lockers	0.628	8.779	No	No	No	Yes	No
Bunk Fnds	0.105	1.468	No	No	No	Yes	No
TOTALS	6.226	87.039					

*Composite Labor Rate $13.98/Hr

NOTE: 2616 tiers (3 bunks/tier)

GROUP 930 MECHANICAL

SHOP NO.	SHOP	LABOR HRS/YR (K)	TOTAL COST/YR (K)	HAZARDOUS UNPLEASANT WORK ENV.	* TOTAL PEOPLE	HIGH VOLUME PRODUCTION
X06	TOOLS	469	5,208	NO	222	LOW
X31	INSIDE MACH	805	9,196	NO	381	MOD
X38	OUTSIDE MACH	1,168	13.425	NO	553	HIGH
X23	FORGE	42	481	YES	20	LOW

* DOES NOT INCLUDE MANAGEMENT

GROUP 920 STRUCTURAL

SHOP NO.	SHOP	LABOR HRS/YR (K)	TOTAL COST/YR (K)	HAZARDOUS UNPLEASANT WORK ENV.	* TOTAL PEOPLE	HIGH VOLUME PRODUCTION
X11	SHIPFITTERS	866	9,844	NO	410	MOD
X17	SHEETMETAL	560	6,340	NO	265	MOD-HIGH
X26	WELDING	855	9,633	YES	405	HIGH
X41	BOILER	130	1,479	NO	62	LOW
X56	PIPE	1,544	17,651	NO	731	HIGH

* DOES NOT INCLUDE MANAGEMENT

GROUP 950 ELECT/ELEX

SHOP NO.	SHOP	LABOR HRS/YR (K)	TOTAL COST/YR (K)	HAZARDOUS UNPLEASANT WORK ENV.	* TOTAL PEOPLE	HIGH VOLUME PRODUCTION
X51	ELECTRICAL	1,267	14,432	NO	600	HIGH
X52	CALIBRATION	199	2,347	NO	94	MOD
X67	ELECTRONICS	1,079	12,282	NO	511	HIGH

* DOES NOT INCLUDE MANAGEMENT

SHOP RANKING

	LABOR INTENSIVE	ENVIRNMENT	HIGH VOLUME
1.	PIPE	FORGE	INSIDE MACH
2.	ELECTRICAL	WELDING	OUTSIDE MACH
3.	INSIDE MACH	PAINT	WELDING
4.	ELECTRONICS	PIPE	SHEETMETAL
5.	RIGGING	OUTSIDE MACH	PAINT

GROUP 970 SERVICE

SHOP NO.	SHOP	LABOR HRS/YR (K)	TOTAL COST/YR (K)	HAZARDOUS UNPLEASANT WORK ENV.	* TOTAL PEOPLE	HIGH VOLUME PRODUCTION
X64	WOOD	530	10,016	NO	251	MOD
X71	PAINT	604	11,922	YES	286	MOD
X72	RIGGING	988	14,951	YES	468	LOW
X99	TEMP SERVICE	386	7,202	NO	183	LOW

* DOES NOT INCLUDE MANAGEMENT

SHIPYARD PROCESS OVERVIEW

PEARL HARBOR NAVAL SHIPYARD

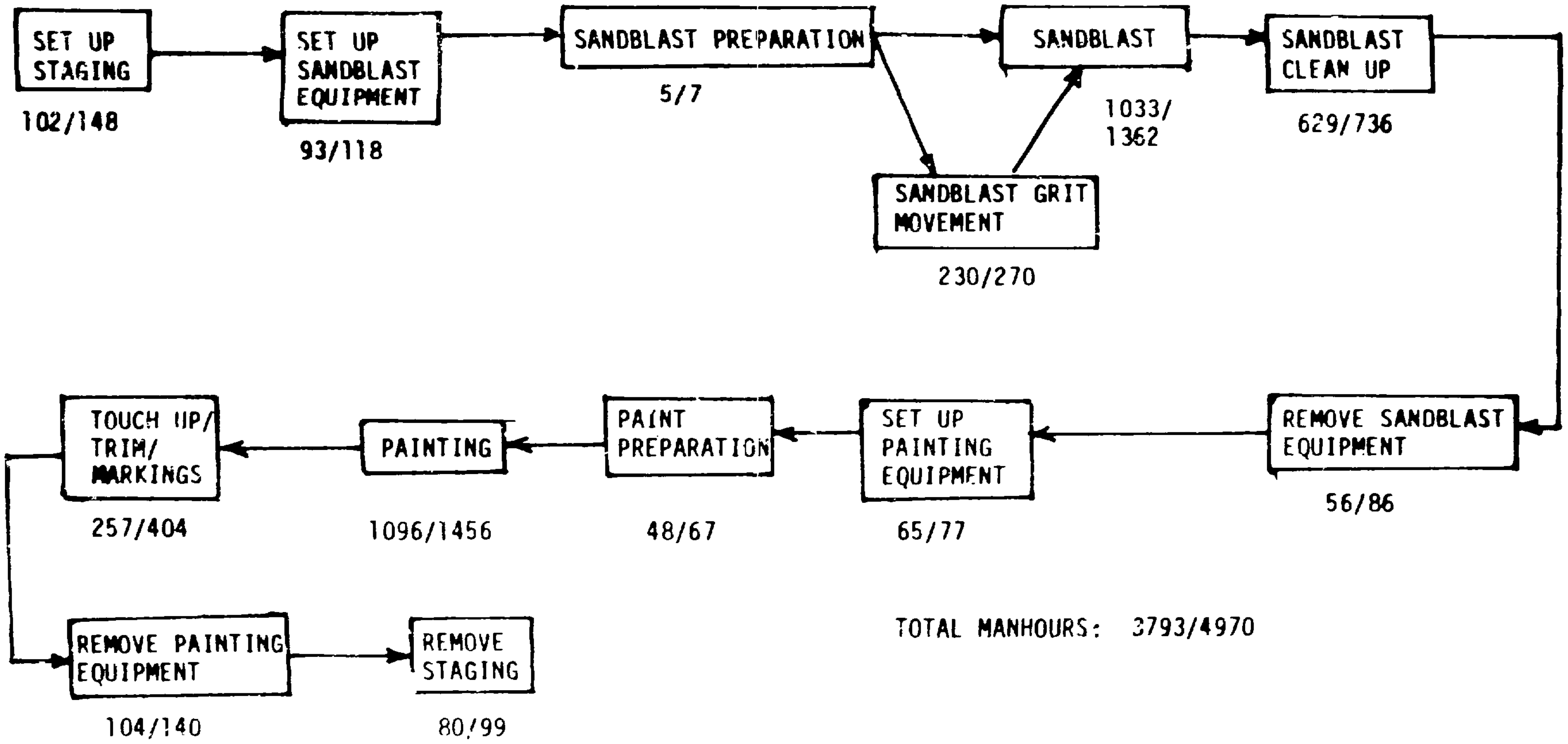
BY: JOEL YUEN

WORK GROUP	AVERAGE ANNUAL WORKLOAD (MANDAYS)	% DISTRIBUTION
Outside Machine	112,000	13.9
Pipefitting	111,000	13,8
Inside Machine	89,200	11.1
Electric	68,500	8.5
Welding	60,400	7.5
Rigging	58,800	7.3
Shipfitting	56,700	7.0
Electronic	48,000	6.0
Painting and Sandblasting	37,400	4.6
Woodworking	32,700	4.1
Sheetmetal	30,800	3.8
Aux Services	29,300	3.6
Boiler Making	23,700	2.9
Insulating	20,900	2.6
Weight Handling	13,100	1.6
Central Tool	5,800	.07
Forge/Heat Treatment	5,500	.07
TOTAL	803,800	

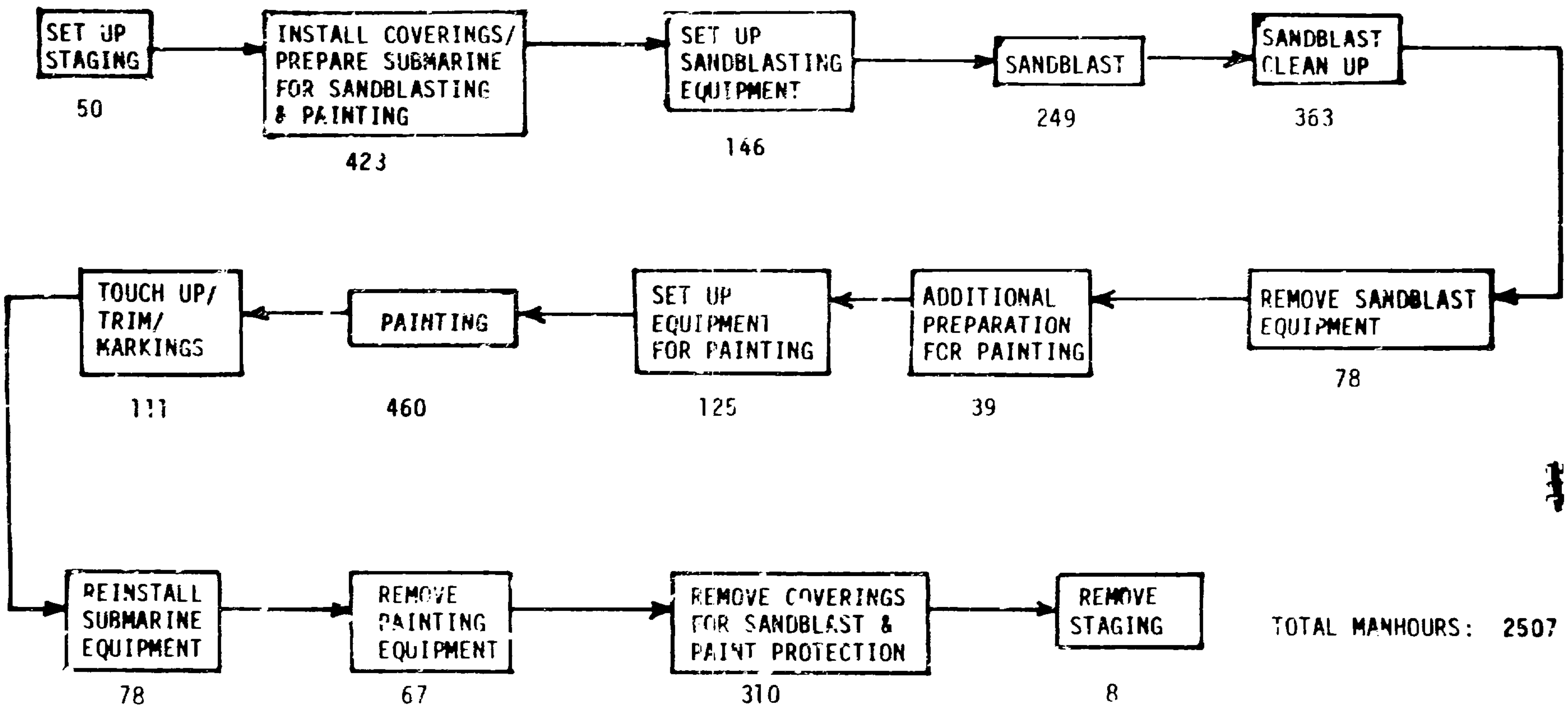
WORK GROUP	WORK DESCRIPTION	% DISTRIBUTION OF LABOR BY SHIP CLASS			
		FF	DDG	CG	SSN
SHIPFITTING	REMOVE, REPAIR, INSTALL STRUCTURAL COMPONENTS	7.3	6.8	7.6	5.5
SHEETMETAL	REMOVE, REPAIR, FABRICATE SHEETMETAL WORK	3.9	3.5	3.8	3.0
WELDING	WELDING AND BURNING OF SHIPBOARD COMPONENTS	6.7	8.4	7.1	5.5
BOILERMAKING	REMOVE, REPAIR, INSTALL BOILER EQUIPMENT	5.8	10.6	6.3	---
INSULATING	RIP-OUT, FABRICATE, INSTALL INSULATION AND LAGGING	3.2	4.3	3.8	1.7
PIPEFITTING	REMOVE, REPAIR, FABRICATE, PIPING SYSTEMS AND COMPONENTS	12.0	13.5	14.4	20.1
CENTRAL TOOL	INSTALL, REPAIR, MANUFACTURE PRODUCTION TOOL EQUIPMENT	.003	.004	.001	.8
FORGE/HEAT TREATMENT	FORGE AND HEAT TREATMENT OF SHIPBOARD EQUIPMENT	.006	.006	.006	.003
INSIDE MACHING	GENERAL MACHINING & CUTTING; PLATING, PUMP, VALVE AND TURBINE OVERHAUL, PROPELLER BALANCING AND REPAIR	10.2	10.5	9.8	12.4
OUTSIDE MACHINE	OVERHAUL OF SHIPBOARD MACHINERY. FABRICATE, ASSEMBLE, REPAIR OPERATRING GEAR FOR FUEL, HYDRAULIC & PROPULSION SYSTEMS.	10.7	10.2	8.1	17.6
ELECTRIC	INSTALL, REPAIR ELECTRICAL MACHINERY & POWER EQUIPMENT, INDICATING & CONTROL INSTRUMENTATION, GYROSCOPES	8.9	7.1	11.6	8.9
ELECTRONIC	REPAIR/MODIFY RADAR, SONAR, COMMUNICATIONS, NAVIGATION, AND WEAPONS SYSTEM ELECTRONICS	8.8	6.7	10.3	4.4
WEIGHT HANDLING	WATERFRONT, DRYDOCK, SHOP WEIGHT & MATERIAL HANDLING SERVICES	1.5	1.0	1.0	1.2

WORK GROUP	WORK DESCRIPTION	% DISTRIBUTION OF LABOR BY SHIP CLASS			
		FF	DDG	CG	SSN
WOODWORKING	BUILD STAGING, DOCKING BLOCKS, LIFE BOAT REPAIR, MANUFACTURE PLASTIC ITEMS, PATTERNS & MOLDS IN FOUNDRY CASTING	4.0	3.2	3.1	2.3
PAINTING & SANDBLASTING	SAND BLAST AND PAINT, HULL DECKS, TANKS, EQUIPMENT. INSTALL DECKING MATERIAL	7.4	4.9	5.1	4.1
RIGGING	TRANSPORT/RIGGING OF EQUIPMENT BETWEEN SHIP & WATERFRONT. ASSIST SHIP DOCKING, UNDERWATER HULL, TANK CLEANING	6.9	5.0	5.1	6.6
AUX SERVICES	PROVIDE TEMPORARY UTILITY SERVICES FOR WATERFRONT AND DRYDOCK WORK	1.9	2.5	2.3	4.9
TOTAL MANDAYS FOR REGULAR OVERHAUL		61,000	110,000	150,000	255,000

PAINTING AND SANDBLASTING OF SURFACE SHIPS



PAINTING AND SANDBLASTING FOR SUBMARINES



TOTAL MANHOURS: 2507

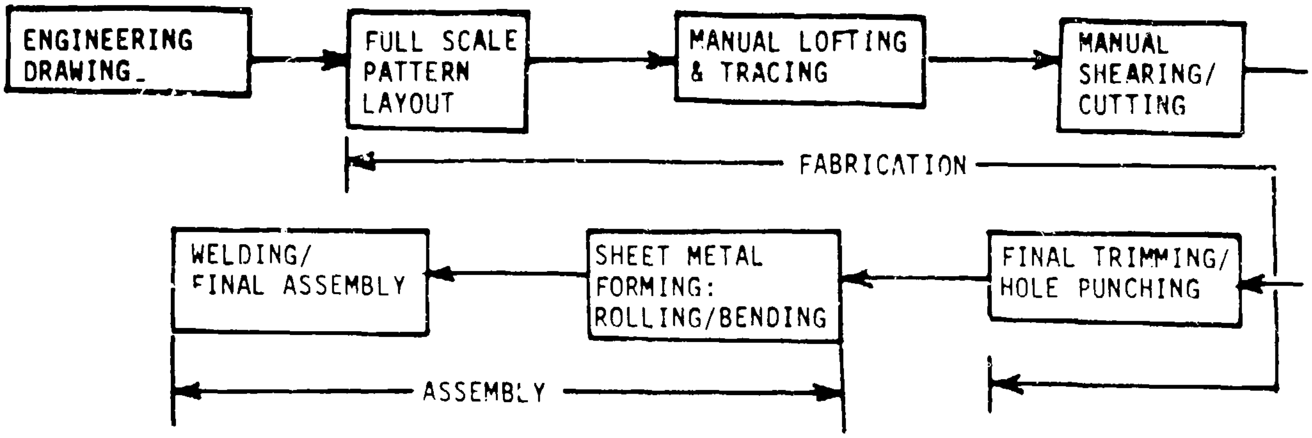
SUMMARY FOR SANDBLAST/PAINTING

TOTAL MANHOURS/SHIP: FF/DDG - 3793
CG - 4970
SSN - 2507

TOTAL MANHOURS/YEARS: 26377

TOTAL LABOR COSTS/YEAR: $790,000

SHEETMETAL FABRICATION



SUMMARY:

TOTAL MAN-HOURS/YEAR:	FABRICATION	- 40,000
	ASSEMBLY	- 20,000
TOTAL LABOR COSTS/YEAR:	FABRICATION	- $1,200,000
	ASSEMBLY	- $600,000

PROPOSED CAD/CAM SYSTEM FOR SHEETMETAL FABRICATION:

CNC SHEETMETAL COMPONENT FABRICATION CELL
NAVY MT PROJECT

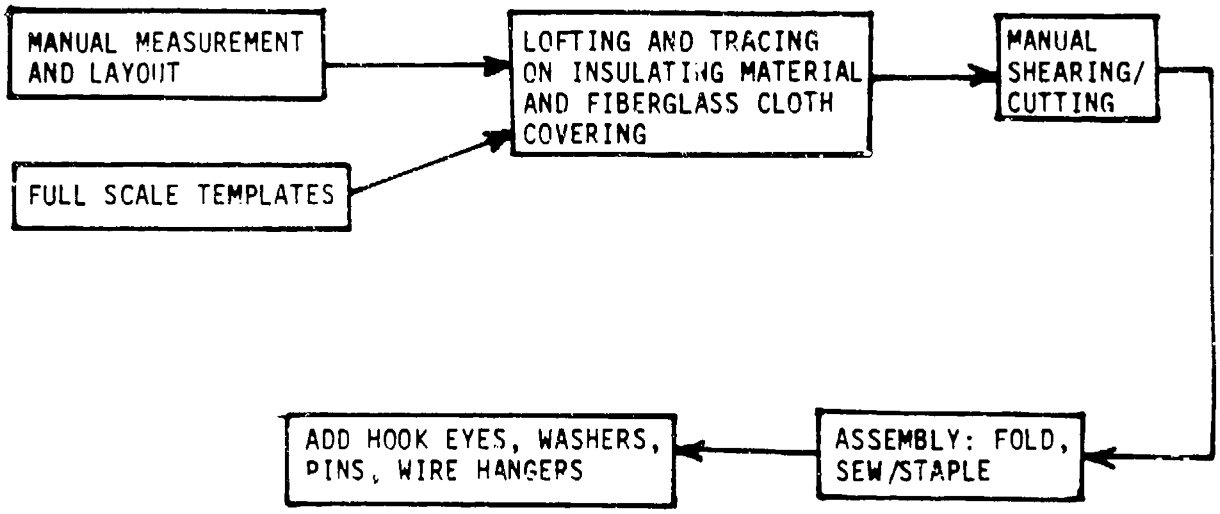
NAVAL SHIP SYSTEMS ENGINEERING STATION

ESTIMATED PAYBACK: $\frac{\$716,000}{.40 \times \$1,200,000} = 1.5$ YEARS

POSSIBLE IMPROVEMENTS:

- ADDITIONAL SOFTWARE FOR VENTILATION DUCTWORK DESIGN
- ADDITIONAL SOFTWARE FOR LOCKING TABS AND OTHER STANDARD SHEETMETAL COMPONENTS
- ADDITIONAL ROBOTICS INTERFACE FOR FINAL ASSEMBLY

FABRICATION OF INSULATION PADS AND SPRAY SHIELDS



TYPICAL SHIP COMPONENTS REQUIRING INSULATION PADS :

- BOILERS
- MAIN FEED, CIRCULATION, LUBE OIL PUMPS
- HP AND LP TURBINES
- MAIN STEAM & AUX VALVES
- STEAM DRAINS
- ALL STEAM SYSTEM FLANGE CONNECTIONS

SUMMARY:

TOTAL MAN-HOURS/YEAR: 9800

TOTAL LABOR COSTS/YEAR: $290,000

OTHER ITEMS THAT MAY BE INCORPORATED INTO THE INSULATION FABRICATION SYSTEM:

- MITERING OF BLOCK AND ROLL INSULATION
  TOTAL MAN-HOURS/YEAR: 2500-3000
  TOTAL LABOR COSTS/YEAR: $75,000 - $90,000

- FOAM RUBBER INSULATION SHAPING
  TOTAL MAN-HOURS/YEAR: 2500 - 3000
  TOTAL LABOR COSTS/YEAR: $75,000 - $90,000

PROCESS ANALYSES AND ROBOT APPLICATIONS AT PORTSMOUTH NSY
By: Kenneth Lanzillo

ACTIVITY:	PORTSMOUTH NAVAL SHIPYARD
LOCATION:	PORTSMOUTH, NH
BUSINESS:	OVERHAUL SUBMARINES
VOLUME:	AVERAGE 4 OVERHAULS/YEAR
COST:	$100 MILLION/OVERHAUL
ROBOTICS:	NONE USED AT PRESENT
MAJOR OBJECTIVE:	REVISE SUBMARINE OVERHAUL METHODOLOG FROM JOB SHOP PRACTICES TO PRODUCTION LINE TECHNIQUES THROUGH USE OF ROBOTIC AND OTHER TIME SAVING METHODS.
GOAL:	REDUCE SUBMARINE OVERHAUL COST AND TIME BY 30%

POTENTIAL ROBOTIC APPLICATIONS

MOBILE SCAFFOLD (FIG 1)

HULL BLASTING (FIG 1)

HULL COATING (FIG 1)

TANK BLASTING

TANK COATING

HULL ACCESS PATCH CUTTING

HULL ACCESS PATCH END PREPARATION

HULL ACCESS PATCH WELDING

HULL ACCESS PATCH WELD NDT

HEAT EXCHANGER CLEANING

HEAT EXCHANGER NDT

IN PLACE VALVE RESTORATION

PIPE WELDING

PIPE WELD NDT

MATERIAL AND TOOL STORAGE AND RETRIEVAL

CURRENT TOUCH LABOR REQUIREMENTS

APPLICATION	HOURS/SUBMARINE	HOURS/YEAR
ERECT SCAFFOLD	17,972	71,888
BLAST HULL	5,904	23,616
PAINT HULL	5,704	22,816
CUT HULL ACCESS PATCHES	633	2,432
END PREPARE PATCH CUTS	1,296	5,184
WELD PATCH	5,802	23,208
NDT PATCH WELD	2,688	10,752

APPLICATION OF ROBOTICS TO THE SUBMARINE OVERHAUL PROCESS

ACTIVITY: PORTSMOUTH NAVAL SHIPYARD, PORTSMOUTH, NH

Historically, submarines have and are still being overhauled on a "Job Shop" basis. This practice, while expensive and time consuming, was necessary because of the large number of submarine classes and the significant difference in configuration between those classes. A typical submarine overhaul today costs about $100 million and removes the submarine from active service for nearly two years.

The submarine Navy of the future will be confined to only two or three classes of submarines, each of which will contain a large number of highly standardized submarines. This profile of the future submarine fleet makes available an unprecedented opportunity to change submarine overhaul methodology from a "Job Shop" basis to a "Production Line" basis. This new methodology significantly increases the potential for applying robotics to the submarine overhaul process.

NAVY SHIPYARD PROCESSES - PORTSMOUTH

Portsmouth Naval Shipyard is currently in the process of developing a conceptual design for a new modern dry dock facility. The design will incorporate innovative techniques and systems, including robotics, that are directed to performing submarine overhauls on a "Production Line" basis. The new facility will result in substantial savings to the cost and time for overhauling submarines.

The conceptual design will consider the use of robotics to perform certain industrial evolutions, such as:

a. Robotic mobile scaffolding system to replace temporary scaffolds and platforms.

b. Robotic sandblasting system for hull exterior.

c. Robotic painting system for hull exterior.

d. Robotic hull patch cutting, end preparation, rewelding and NDT system.

e. Robotic sandblasting system for main ballast tanks and internal tanks.

f. Robotic painting system for main ballast tanks and internal tanks.

g. Robotic inplace cleaning and NDT for heat exchangers.

h. Robotic inplace restoration of welded-in hull valves.

A summary briefing of the first four potential robotic applications are included herein as Attachments (1) through (3).

TEMPORARY SCAFFOLDING*
SIMPLIFIED PROCESS INFORMATION MATRIX

PROCESS	TOUCH LABOR HRS/SUB O/H	HAZARDOUS/ UNPLEASANT WORK ENV.	LABOR SKILL
Install, inspect, maintain and remove gangways, catwalks, & staging. Provide platforms for temporary facilities equipment.	15,424	No	Low
Fabricate and install misc. items to support above.	2,548	No	High

Total labor hours per submarine = 17,972 hours

Total labor hours per year = total labor hours per submarine x number submarine O/H's/year
= 17,972 x 4
= 71,888 hrs/year

*Consideration should be given to developing a combined robotics system to:

a. Provide a mobile scaffold as shown in Figure 1.

b. Replace scaffold cab with self-contained robotic sandblasting unit.

c. Replace scaffold cab with robotic painting unit.

SANDBLASTING & PAINTING HULL
SIMPLIFIED PROCESS INFORMATION MATRIX

Apply protective temporary coverings	1664	No	Low
Blast entire hull including bow dome	3224	Yes	Mod-high
Remove spent grit	1016	No	Low
Inspect & prime blasted area	564	Yes	Mod-high
Paint hull	3930	Yes	Mod-high
Remove protective coverings	986	No	Low
Repair damaged paint areas	224	Yes	Mod-high

SANDBLASTING & PAINTING HULL
SUMMARY ANALYSIS

Apply protective coverings	Blast entire hull	Remove spent grit	Inspect prime hull
1664 hrs.	3224 hrs.	1016 hrs.	564 hrs.
Paint hull	Remove protective coverings	Repair damaged paint areas	
3930 hrs.	986 hrs.	224 hrs.	

Total labor hours per submarine = 11,608 hrs.

Total labor hours per year = labor hours/submarine x submarine overhauls/year

= 11,608 x 4

= 46,432 hrs/year

HULL PATCH
SIMPLIFIED PROCESS INFORMATION MATRIX

PROCESS	TOTAL LABOR HRS/PATCH	HAZARDOUS/ UNPLEASANT WORK ENV.	LABOR SKILL
Scribe patch layout. Cut and remove patch.	106	Yes	High
Bevel hull opening & frames.	112	Yes	High
Bevel patch and frames.	104	Yes	High
Reinstall patch.	140	Yes	High
Blockweld patch to hull.	85	Yes	High
Weld patch to hull.	463	Yes	High
Contour grind welds.	147	Yes	Mod.
Clean weld for NDT	24	Yes	Low
RT and MT joint.	368	Yes	High
Weld repair defects.	60	Yes	High
Final check/inspection.	32	No	High
Clean weld repair for NDT	16	Yes	Low
RT and MT weld repair.	80	Yes	High

HULL PATCH
SUMMARY ANALYSIS

Scribe, cut, remove patch	End prep cuts	Reinstall, weld patch	Grind, clean,weld
106 hrs.	216 hrs.	688 hrs.	171 hrs.
RT/MT Weld	Weld repair defects	Grind, clean weld repair	RT/MT weld repair
368 hrs.	60 hrs.	48 hrs.	80 hrs.

Total labor hours per submarine = labor hrs/patch x number patches

= 1737 x 6

= 10,422 hrs/submarine

Total labor hours per year = labor hours/submarine x submarine overhauls/year

= 10,422 x 4

= 45,688 hrs/year

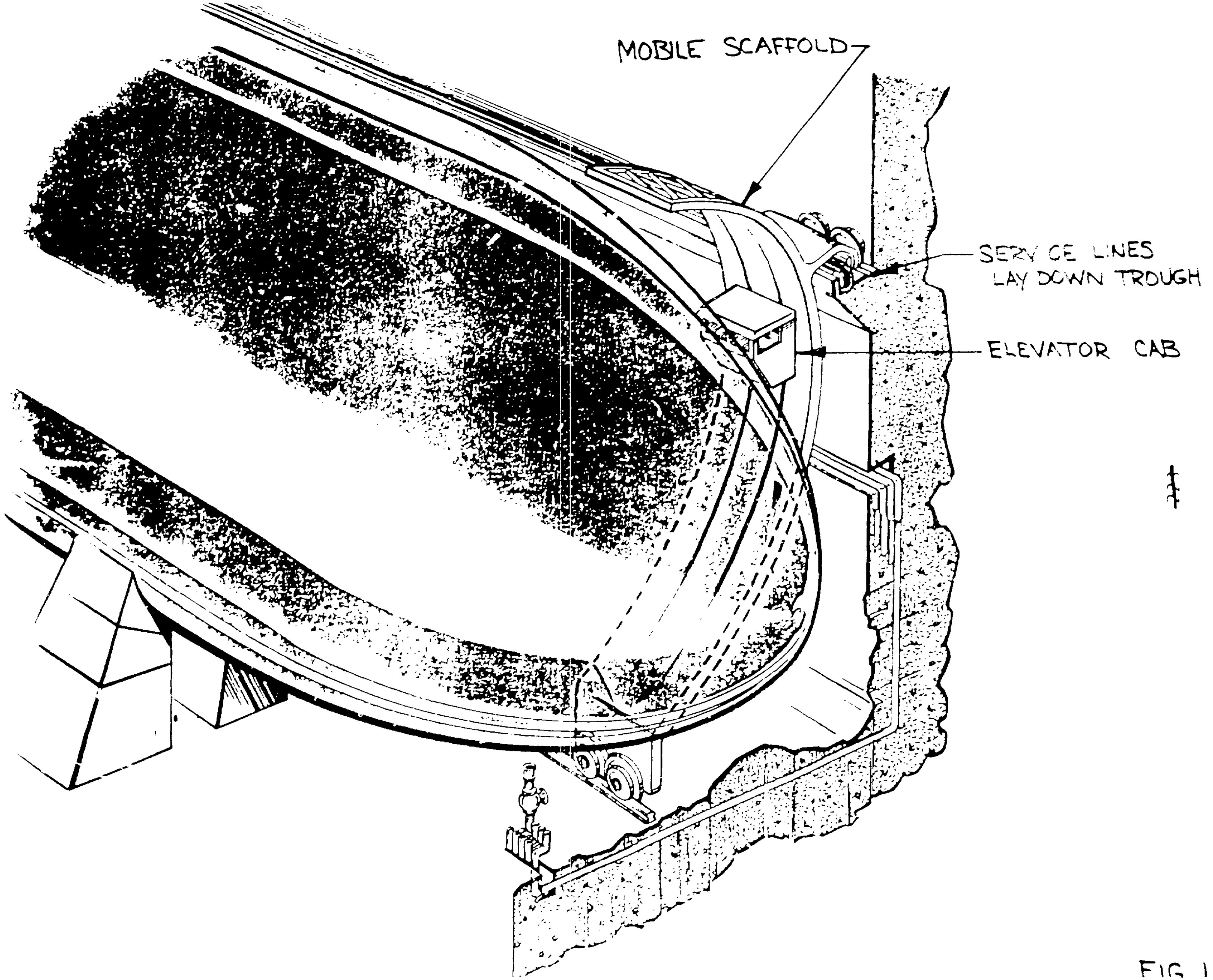


FIG 1

DEPARTMENT OF THE NAVY
PUGET SOUND NAVAL SHIPYARD
BREMERTON WASHINGTON 98314

IN REPLY REFER TO

14 Dec 83

Forrest Gale, Service Chair
DOD Robotics Application Workshop
Defense Systems Management College
Fort Belvoir, Virginia 22060

Subj: DOD Robotics Application Workshop Depot Process Review from
Puget Sound Naval Shipyard, Bremerton, Washington

Presentation by M. S. Wixson, Structural Group Superintendent

Introduction: Puget Sound Naval Shipyard located at Bremerton, Washington. Employees - over 12,500 people. The Shipyard has the capability to build or overhaul any ship in the fleet. PSNS has only a small start in the field of robotics.

Slide #1 - This logo was prepared for our 1983 Armed Forces day celebration which included a robotics demonstration. The logo features the apprentice robot. In addition to a welding demonstration, the apprentice robot was programmed to pour refreshments for the visiting public. This innovation contributed to the popularity of the exhibit.

Slide #2 - This is a look at our organization relative to robotics application.

- Although our first robot was acquired through the efforts of our Welding Shop and Production Engineering we look to NAVSEA and our CAD/CAM Steering Committee for guidance and support.

- Our Structural Group Planning team ties our efforts together.

- Our robotics coordinator works with Production Engineering, the shop equipment section and shop planning to move robotics into the production mainstream.

Slide #3 - Our first robot, Unimation's apprentice robot was delivered in December 1982

- Funded through the fast pay back program for $48,000.

- Designed specifically for welding.

- Lightweight - portable for shop or ship.

The "teach" control is the outstanding feature. Simply slip the teach control over the welding gun nozzle, lead the robot by the arm through the path to be welded and the program is automatically recorded.

NOTE: Referenced slides were not included for Proceedings.

•Operates in a 35" x 64" x 16" envelope.

•Total of 14 weld segments possible.

•Capability of 27 linear feet of welding.

The control panel includes speed, dwell, oscillation, and welding current adjustment.

•The operator does not need computer training or knowledge - simple.

Slide #4 - Typical apprentice production weld job accomplished in three weld segments.

•During this first year of operation we have qualified the robot for welding on:

HY 80	GMA spray transfer	
CRES	" " "	
CFe	" " "	
"	dual shield	

•Six operators have been qualified.

A problem has been encountered in tracking. Our first unit was replaced because of this tracking problem. We have now experienced the same problem in our second unit after a considerable number of hours of trouble free performance.

Slide #5 - Here is another form of robotics application. This is an Eaton Leonard Vector I tube data center -- a digitizer which transmits pipe shape data to a computer. We have two of these units in operation in our Pipe Shop and Boiler Shop.

•To get pipe shape and length pick up end points and each straight section between bends.

•Capacity of 20' in length and 3" diameter.

Slide #6 - After physical points have been picked up and recorded inputs are made for spring back, elongation and bend radius. This information is then fed to the pipe bending machine.

Slide #7 - The pipe bender operates in the x y z axis. The pad under the operator is the safety interface in the working envelope.

We have looked at other potential applications for robotics. One natural application was found in our pipe shop.

Slide #8 - Here is a pipe hanger in various stages of fabrication excluding welding.

Slide #9 - Flatbar, sheared.

Slide #10 - Flatbar, formed on press

Slide #11 - Holes punched

Slide #12 - Pipe hanger assembled

•A natural candidate for robotics.

•Labor intensive - boring job

Slide #13 - We also looked at our Sheet Metal Shop for utilization of robotics. An excellent candidate was found in our door fabrication unit.

•PSNS is the west coast facility for door manufacture for the NAVY

•12 types of door manufactured

Slide #14 - Fixtured assemblies used for repetitive operations

Slide #15 - Welds surface finished

•Aluminum

•Excellent fit up

•GTA cold wire welding

Slide #16 - Another natural job for robotics. The manufacture of 2,400 shelves.

•9600 corner welds

PSNS leads Naval Shipyards in thermal sprayed coatings. At that we have only scratched the surface in the application. With an estimated FY 1983 cost of $800 million to the Navy for corrosion of ships, there is lots of room for robotics in thermal sprayed coating application.

Slide #17 - Here is a look at arc wire sprayed aluminum applied for corrosion control.

•Environmental concerns drive robotic consideration.

Slide #18 - Another application of arc wire sprayed aluminum.

Slide #19 - Plasma powder sprayed coatings on rotating equipment. Another job for robotics.

Slide #20 - A typical plasma powder sprayed product. Ceramic coating on a steam valve.

•Process developed at PSNS.

•Potential one million dollar savings/yr in valve steam replacement at PSNS.

Slide #21 - Completed babbit bearing arc wire sprayed.

•Environmental concerns dictate robotics consideration.

Slide #22 - Chart of our thermal spray organization.

•Note assignment of robotics responsibilities on right side.

Summary - We at PSNS only have our foot in the door when it comes to acquisition and utilization of robot. We are looking forward to the challanges and rewards of robotics.

M S Wixson

M. S. WIXSON
Group Superintendent, Structural
Puget Sound Naval Shipyard

P.S.N.S.

ROBOTIC PLANNING FLOW

NAVSEA CAD/CAM

PSNS CAD/CAM STEERING COMMITTEE

STRUCTURAL GROUP PLANNING

SHOP EQUIPMENT SECTION - ROBOTICS COORDINATOR - PRODUCTION ENGINEERING

SHOP PLANNING

PRODUCTION

ANALYSIS OF DEPOT OPERATIONS

LETTERKENNY ARMY DEPOT

Jerry Nitterhouse/Steven Kalabokes

Letterkenny Army Depot (LEAD) is a member of the DARCOM depot system which includes twelve such facilities. Co-located at LEAD and immediately accessible to the depot's work force are the headquarters, Depot Systems Command, and the Commanding General Staff. LEAD also shares a portion of its facility with the DARCOM Logistic Systems Support Activity (LSSA). Together these organizations employ some 5500 people with LEAD personnel accounting for 4300 civilians and 70 military personnel. On an approximate assigned basis of personnel, 2600 comprise the Maintenance Directorate, with Supply and Base operations accounting for about 800 employees per organization. The depot organization consists of a series of directorates which includes Maintenance, Quality, Supply, Base Operations, Management Information Systems and Resource Management. The latter organiztion includes the depot Comptroller and supports the balance of the depot directorates. Due to the broad spectrum of our mission responsibilities, virtually every skill, trade, and profession is incorporated at LEAD. LEAD therefore has a significant pool of source personnel who are prepared to accomplish missions as required or deemed pertinent to the support of the US Armed Forces. During FY 82, LEAD procured 51.4 million dollars worth of material and services. This figure includes expenditures for direct services, capital equipment, and construction. On a yearly basis, approximately 26 million is contracted to small businesses. Because the majority of our workforce resides in an area immediately adjacent to the depot, a significant percentage of this payroll supports local business organizations.

The major portion of the Maintenance Directorate's workload for FY 83 was dedicated to combat vehicle components and missile systems. Our industrial facilities for supporting wheeled and track vehicle maintenance is Building 350, which encloses approximately 300,000 square feet. This facility contains all the necessary equipment and capabilities to restore even badly combat damaged vehicles to like/better than new condition. In 1980, we added a 65,000 square foot annex which houses a complete machine and metal working facility. The supply operations in Building 350 are supported by an 11,000 bin computerized automatic storage and retrieval system. The other major industrial area is Building 370, which houses our missile and electronic shop. This is the area of our primary mission and constitutes approximately 59% of the maintenance workload. Our primary customer is the Missile Command in Alabama. The primary systems supported by this facility are the Nike Hercules, I-Hawk, and Patriot Air Defense Sytems. This facility is capable of supporting a broad spectrum of electronic systems ranging from antiquated vacuum tube, to state-of-the-art multilayer solid state technology. Test and Instrumentation equipment varies from common bench units to fully computerized automatic test equipment. Other support maintenance functions include engine and powertrain overhaul, and computerized diagnostic testing, complete optics facility with coating and lens grinding capabilities, hydraulic test and rebuild, artillery overhaul, van and shelter repair, and many additional capabilities which are too numerous to mention. Our planning for long range

depot improvements covers a wide array of technologies and occupational specialties. As part of the DESCOM wide system upgrade, new administrative technology on the shop floor will tie our functional areas directly to the parts requisitioning and inventory system through a centralized filing system, using computer terminal input devices on the shop floor. The existing automatic storage and retrieval system will undergo a 12 million dollar modernization and enlargement program during FY 84. We are presently involved with the contract phase for construction of a robotic blast cleaning facility which is as unique to the private sector as it is to the Army. LEAD is presently performing engineering studies to determine the technical and economic feasibility of implementing robotic camouflage painting, laser engraving and agricultural blast cleaning some of which will also incorporate machining intelligence systems. A 5.5 million dollar enlargement program is in the construction phase at our guided missile facility. Letterkenny Army Depot is committted to a total modernization effort to improve the Army's production base to insure a ready and strong national defense.

--ABSTRACT--

CURRENT OPERATIONS AND ECONOMICS OF WELDING, PLATING, PAINTING, AND VAN ASSEMBLY

By: E. Helalian

Sacramento Army Depot

Mr. Helalian is robotics project officer, responsible for systems analysis of production processes, and prioritization and recommendation of robotics projects and applications. The Sacramento Army Depot has 500 acres and 2600 people, and overhauls, repairs, and remanufactures electronics and communications systems and equipment.

The presenter reviewed the current process operations in the Sacramento Depot welding shop and van production drilling and riveting operations, all of which have been identified as robotics applications areas of high potential payoff.

The welding shop does both fabrication (75%) and repair (25%). The sheet metal shop feeds the weld shop, which does assembly and welding as well as production of fixturing. The average weld job has 50 pieces and takes 40 hours to complete including clean up/grinding. TIG, MIG, Heliarc, and arc weld processes are all used. MIG welding, a wire spool driven inert gas process, is the fastest and provides very uniform results. The TIG process is slower and produces very strong welds. Both are amenable to robotics application.

Van assembly involves drilling and riveting of shelves and ducts for equipment assembly using templates. Three-man teams do the work, investing approximately 40-man hours/van. Rivet insertion is done by gun. This potential application area for robotics is currently under study at the depot.

ARMY DEPOT PROCESS

RED RIVER ARMY DEPOT

WALTER OOSTERVEEN

We have three major functions at the Red River Army Depot. These are Maintenance, Supply and Ammunition.

I represent the Maintenance Directorate and our primary mission is to support the US Army both CONUS and Overseas. This includes the National Guard. We rebuild combat vehicle carriers, mainly the 113 FOV in all nine configurations.

FY 83 saw us rebuild and modify 1560 vehicles. These vehicles come in for periodic overhaul. At this time, the vehicle is completely overhauled and any modification which is applicable is performed. When we say overhauled, we mean that it is completely taken apart right down to the last bolt and nut and rebuilt from the ground up to standards which are as good if not better than new condition.

Because the actual process from start to finish would take more than my allotted time, I want to be more specific, narrow it down so to speak and select three separate items and give you a brief description of the method which we use to disassemble two of these items and modify the third.

It so happens that these items are currently involved in projects which will include robots. I will tell you about these projects a little later in the day.

Army has been in the repair/overhaul/rebuild for a long time. Red River Army Depot has been a member of this team for about 41 or 42 years. I might add that some of our equipment and methods are just about that old.

I'm glad that the DOD has opened it's eyes to the fact that we need to modernize. It's with this in mind that we in the Maintenance Modernization Branch at Red Riber Army Depot are looking at some of our outmoded techniques and hopefully sometime in the not too distant future we will have up-to-date equipment and methods.

SINGLE PIN TRACK DISASSEMBLY AND DENUDE
(Current Method)

Currently a roll of track is placed in a hopper and unrolled onto a long disassembly conveyor with the use of winch and cable. Two men, using pneumatic wrenches remove the nuts on one side of the track pin and the nuts which hold the inner track pad in position. The track pads are tapped out and a hand held impact wrench pushes out the track pins. The disassembled track shoe is now manually stacked on a pallet to be transported to the salt vat area. At this station, two men unload the track shoes from the pallet to a basket which in turn is lowered into a liquid salt vat which is heated to 600°F and allowed to soak. After soaking for 20 minutes, the basket is removed from the vat and the rubber is pried from the shoe. Finally the bushings are mechanically pushed from the shoe and the shoe allowed to cool. After cooling, the shoe is inspected for cracks and placed in a bin to await the next operation.

This method of disassembly and denude takes an average of 3.8 minutes per shoe.

The salt vat operation is of such an undesirable nature that the operators are assigned to this area for a short period of time (ten working days) and then rotated to another station in our Rubber Products Branch. This is truly a hazardous job and requires the operators to wear helmets equipped with fresh air being pumped into the helmets. This is a safety requirement to avoid lung contamination as cancer causing carcinogens arise from the vat as a result of the rubber on the shoes which reacts to the molten potassium and sodium nitrate mixture. This factor alone is enough to merit going to a method which will totally eliminate this condition and stay within OSHA Standards of safety.

DOUBLE PIN TRACK DISASSEMBLY DENUDE
(Current Method)

A roll of track shoe assembly is placed into a hopper where it is unbanded. The loose end is hooked onto a winch cable and the track is pulled out of the hopper onto a conveyor. The dried mud and debris is chipped out with a chipping hammer around the wedge bolts and center guides. The nuts and bolts are removed with pneumatic wrenches. The assembly is turned over with the use of the overhead crane grouser side up and moved to the next station where the end connectors are pulled off. The track shoes are now manually stacked on a pallet to be transported to the next station. This station has a heat induction furnace where the track shoe is heated to 300°F for 30 seconds and quickly transferred to a pin removal press. The pins are pressed out and the track blocks are placed on a conveyor where they are moved to another station which has a heat induction furnace. The track blocks are reheated to 300°F for 30 seconds and quickly transferred to a pin removal press. The pins are pressed out and the track blocks are placed on a conveyor where they are moved to another station which has a heat induction furnace. The track blocks are reheated to 300°F and quickly transferred to a special station where the rubber is ripped off with a special hydraulic tool. The insert is now placed in a container to await the rebuild cycle.

The total time to disassemble and denude one roll of double pin track is 10.25 hours.

A full roll of track contains 80 track shoe assemblies. Average time per assembly is 7.69 minutes.

This is labor intensive and a better and more efficient method must be found. Also, the denuding part of this operation is a hazard to the individuals who perform this work. Because of the heat being applied, cancer causing carcinogens arise from the rubber and the workers need to be protected. Their protection is a hood with compressed air being pumped into it. This job requires that personnel be rotated to another job every two weeks. This is another factor toward acquiring a system which will eliminate the hazardous conditions plus do the operation in a more efficient manner.

WELDING OF M113 SUSPENSION

(Current Method)

The current welding procedure requires the following welding after the hull has been machined:

1. A two inch thick aluminum idler plate is welded into position in the vertical plane. Welding is required around the contour of the plate on both inside and outside of the hull. An upside down (or overhead) weld is required along the bottom contour of the plate.

2. Six bored holes are puddle welded closed. These are welded in a vertical plane.

3. Three round plugs providing stiffness are contour welded also in the vertical plane.

4. A rectangular bumper plate must be contour welded to the sponson entirely upside down (or overhead).

5. Additionally, on the right side, a stiffener plate is contour welded to the back of the two inch plate that protrudes to the rear outside of the hull.

All of the above welding is done manually by two welders. To keep warpage and heat build-up to a minimum, the welders must alternate between the inside and outside of the M113 hull, laying only one bead at a time, resulting in a tedious and time consuming operation. After welding, the excess weld is disc ground to blend with the original surface.

This operation requires a total of 11 hours. When you multiply that by 1260 vehicles or more to be rebuilt each year for the next 5 years, it is understandable why RRAD seeks a more efficient and economical way of welding the suspension plates on the M113 hull.

This concludes my presentation this morning.

APPLICATIONS OF ROBOTICS TO SHELTER REFINISHING

TOBYHANNA ARMY DEPOT

MR. FRANK ESTOCK

The process that I will discuss is one to which we are presently attempting to apply robotics. This is the overhaul of communications-electronics shelters.

Tobyhanna Army Depot is located in Northeastern Pennsylvania. Our primary mission is the overhaul of communications-electronics systems. We are different from most depots, in that 60% of our workload is overhaul, while 40% is what we call "new work". Overhaul includes the rebuild/repair of radios, telephones, teletypes, up to sophisticated microwave communication systems. New work is the design, development and fabrication of new weapon systems such as the satellite communication ground stations. This could be the fabrication of a prototype or a production run when a private contractor cannot do the work. Presently, Tobyhanna employs approximately 4,000 people, and Maintenance occupies 700,000 square feet.

A shelter is an aluminum-skinned box which varies in size from one which fits on the back of a pick-up truck, to a 40-foot van. These shelters are constructed of two thin aluminum skins laminated onto an insulating material. Obstructions such as doors, air conditioners, power entrance panels make the sanding or painting of these shelters difficult.

In 1970, only 100,000 manhours were devoted to shelter work, but today we process approximately 950 shelters each year. In three to five years, this is projected to double.

Now I will discuss the present shelter workflow. First the shelter is disassembled. All black boxes, racks and electrical ducts are removed and sent to the respective repair areas. The shelters are then sent to the sheetmetal repair area, which is similar to an auto body repair area. Here the shelter is repaired or patched. Next, it is sanded and prepared for painting and eventually painted. After the shelter rebuild is completed, all the components are kitted and married with the shelter in an assembly area. After assembly, the final testing is performed. This may be a computer test of all the components, or a full operational test which could involve aligning communication disks with a satellite and bouncing signals to another installation. The workflow seems haphazard since there is a need to separate the dirty and dusty operations such as the body work, sanding and painting, from the repair of the sophisticated electronics gear. The sanding and sheetmetal repair is performed in temporary buildings in the outer areas.

Shown in Figure 1 are the times required to perform the operations to which we will be applying robotics. Presently, these sanding and painting operations are all done manually. An overahul shelter is one that is being returned from the field. They usually require extensive work, as reflected in the hours shown. A new shelter is one received directly from the manufacturer. Some touch-up sanding and painting is required, since holes must be cut for air conditioners or power entrance boxes. Time required for camouflaging is almost the same as for shelters being overhauled.

CATEGORY OF SHELTER	APPROXIMATE TIME TO SAND	APPROXIMATE TIME TO PAINT (ONE COLOR)	APPROXIMATE TIME TO PAINT (CAMOUFLAGE)
OVERHAUL	12-20 HRS	4-5 HRS	8-23 HRS
NEW	6-10 HRS	3-4 HRS	6-11 HRS

Figure 1

NOTE: TIME IS DEPENDENT UPON SIZE, SHAPE COMPLEXITY AND DEGREE OF FINISHING REQUIRED PER SHELTER CONFIGURATION. OVERHAUL SHELTERS GENERALLY REQUIRE REFINISHING OF THE INSIDE SURFACES WHEREAS "NEW" SHELTERS DO NOT

Work in the sheetmetal repair area can involve the replacement of entire sections of the shelter, or simply patching holes with a body filler. This operation includes cutting the sheetmetal, riveting it into place, sanding, caulking, and sealing.

The sanding of shelters is done with hand vibrating sanders. Usually only a light sanding is required to smooth the surface to prepare it for painting. If there is excess paint on the shelter, then in some cases the entire surface has to be sanded to the base metal. This is a lengthy and difficult job. The employee in each case must wear a respirator hood to protect him from the lead and chromate dust particles that become airborne from the paint that is being removed. Sanding the inside is the most hazardous operation for the employee.

Major painting is presently done inside a large paint booth. Again, the employee must wear a respirator hood. With the new requirement to apply CARC to shelters, the employee is being subjected to a more hazardous working environment.

Upon completion of our present modernization program, both in facilities and by applying robotics, operations will be consolidated and processes placed closer together. It will reduce our turnaround time to process a shelter from seven months to three or four months, while saving money and producing a quality end item.

Robotic Handling of Hazardous Materials

Tooele Army Depot

Fred Eldredge

The Ammunition Equipment Directorate (AED) is an organization of technical experts with the mission to design, develop, manufacture, and test equipment and procedures for the maintenance, modification, renovation demilitarization of explosive and chemical filled munitions throughout the Department of Defense. The directorate consists of approximately 100 engineers, technicians, equipment specialists, draftsmen, machinists, and administrative personnel.

Areas of expertise include: equipment and machine design, shield barricade design and testing, robotics, sawing/shearing of explosives incineration of ammunition/explosives and hazardous waste, development of demilitarization processes, both chemical and mechanical, conduct of special studies related to ammunition, and ammunition related environmental impact analysis.

Our involvement in the use of robotics was a natural step due to the expense of providing for the safety of the human operator as the government standards for such safety requirements increased. Our addition of shielding and barricading both from a design and cost standpoint became very difficult.

Very simply stated, we found that if we could remove the human element from the machine, we could then place the operation away from all personnel, let the robot do the material handling and reduce the shielding or remove it from the machine entirely.

Barricade cost which alone could equal the cost of procuring a robot was reduced; safety factors improved greatly, and maintenance costs decreased because the removing of the barricade allowed easier access to the machines when service was required.

By way of past history, AED began their experience with robots in 1968 when they incorporated two Versatran robots in an automated line to demil M34 cluster bombs at Rocky Mountain Arsenal. These robots were fitted with special tooling to individually remove each of the 76 M125 bomblets contained in each M34 cluster bomb. This tooling provided a vacuum head to pick up the bomblet; means for separating stuck bomblets from each other; means for holding the piggy back delay wire and fuze arming ring in position during bomblet transfer to subsequent operations, and contained an integral electro mechanical system to prevent damage to the tooling and robot arm by accidental side overloads. This latter system used electronic sensors interconnected with the robot control logic and servo valves, to sense overload, stop the robot, and to cause it to retrace its last motion for several inches, thus, relieving the overload and resetting the tooling. Rapid sensor and system response time were essential.

Since most robots can pick up items only from a pre-programmed position, it was necessary to place the cluster at a known position and to remove the ouside casing to allow access to the items. We designed the case cradle to do this material handling chore.

The staker machine is the final destination of the bomblet and the start of the demil process.

Sensors were needed to give control over the operation simply because of the hazards present. An operational failure could result in extensive equipment repair. Because of operator programming error, we experienced excessive download pressures being applied to the neoprene vacuum cups resulting in damage to the sealing edge. With a vacuum level switch setting, we checked each vacuum setting before the robot would lift off with the bomblet to assure that vacuum failure would not release the bomblet between its travel to the set down point. But, replacement of this cup became a large maintenance problem. Also, there was always possible damage when one of the operators would crash the manipulator into other foreign objects.

To solve this difficulty, we added sensors which first would allow only so much pressure to be applied to the neoprene vacuum cup before it would signal the operator to correct the problem, or if he continued to apply more pressure than the system would shut down to prevent damage. Second, we installed some circuitry in the analog servo amplifier to reverse the manipulator if excessive flex was detected at the pivotal joint, indicating crash force was being applied.

The second project was the installation of a Unimate 2000 B in a 40mm renovation line at TEAD. This robot was modified and certified to meet factory mutual and DARCOM-R 385-100 standards for use in explosive areas. The robot was interfaced with three Ammunition Peculiar Equipment (APE) detracing machines. This required addition of appropriate sensors and interfaces with the machine controls. The machine functions were controlled and monitored by the robot controller. In addition, the projectile orientation was automatically sensed at the pick up station on the feed conveyor, and the robot wrist rotated it to the correct orientation for processing in the detracing machines. This operation was first set up in a test facility and debugged and then installed in the ammunition line. Rounds are detraced at a rate of 780 rounds per hour. This operation replaced three operators who were assigned to other duties, and production increased greatly over manual methods. Operation is still in production with a new run of projectiles scheduled to start this year.

In the 40mm renovation line, the projectiles are delivered to the robot and three modified APE 1002M2 defuzing machines from an adjacent cubicle. Since the operation is judged to be hazardous, the total process is done automatically, and personnel are not allowed inside the area while live rounds are being processed.

If a malfunction occurs, the robot halts and signals an operator to enter and correct the problem, a safety lockout or hold switch is activated on the outside of the cubicle before the entry is made so the machine cannot be accidentally activated.

The projectile can arrive from its conveyor delivery system in a choice of two different orientations so there are sensors to select one of two programs to make sure that placement is correct in the machines when they are loaded.

The robot as before mentioned basically keeps filling the three machines with new projectiles and unloading the rounds after the tracers have been removed. Control of all three machines is accomplished by use of the robot controller which must start the process and monitor all sensors.

The Directorate for Ammunition Equipment has been involved with other projects from an engineering design standpoint, and as a consultant to other DOD type work.

Next year we will be receiving four Cincinnati Malacron Robots which will be applied to interface with existing ammunition equipment. Some delay in receiving these units has been experienced because of the factory mutual safety rating required to allow use of these machines in hazardous environments.

Much of my personal efforts this year have been spent in design, fabricating, and testing of the HEL field demonstrator which has been mentioned today.

I have observed countless opportunities for the government to increase the productivity of its labor intensive manufacturing, renovation, and demil plants. Hopefully, a serious effort and investment of capital will be made toward the use of more robotic systems. My past experience has demonstrated that where an application has been properly engineered, the investment has been paid back in a very short period.

NAVY WEAPONS STATION PROCESSES
BY: DON WHIRLEY

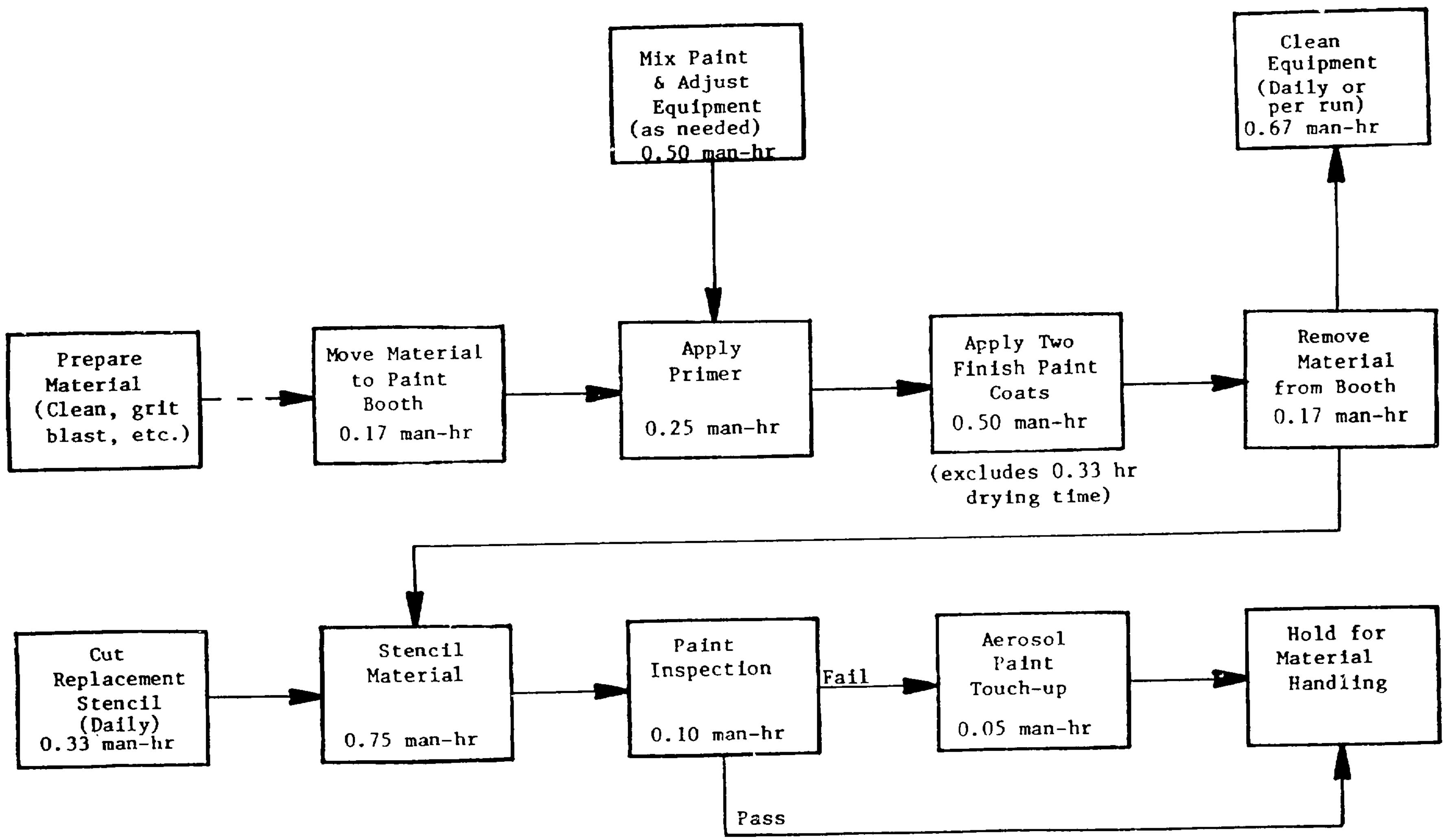
Figure 1: PROCESS INFORMATION MATRIX
CHARLESTON NAVAL WEAPONS STATION
DOD Depot Robotics Workshop

ORDNANCE PROCESS	LABOR HR/YR	LABOR COST/YR	HAZARDOUS/ UNPLEASANT WORK ENVIR?	SPECIALIZED SKILLS REQ'D	REQUIRED JOB TRNG	HIGHLY REPETITIVE?	KEY OPN' COMMON T OTHER PR
Welding	3,532	$ 105,960	Yes	High	2 Yrs	No	Yes
Metal Cutting/Forming	4,415	132,450	No	High	2 Yrs	No	Yes
Electrical Testing	11,982	359,460	Yes	High	3-6 Mos	Yes	No
Electrical Testing	13,696	410,880	No	High	7-12 Mos	Yes	No
Disassembly	82,392	2,471,760	Yes	Med/High	3-12 Mos	Yes	No
Assembly	60,374	1,811,220	Yes	Med/High	3-12 Mos	Yes	No
Assembly	36,256	1,087,680	No	High	3-4 Mos	Yes	No
Material Handling	35,320	1,059,600	Yes	Med	1 Yr	Yes	Yes
Material Handling	10,709	321,270	No	Low/Med	1 Mo	Yes	Yes
Mat'l Movement/Routing	22,512	675,360	Yes	Low	3-6 Mos	Yes	Yes
Mat'l Movement/Routing	3,051	91,530	No	Low	1 Mo	Yes	Yes
Packaging	39,439	1,183,170	Yes	Low/Med	3-6 Mos	Yes	Yes
Packaging	4,300	129,000	No	Low	1 Mo	Yes	Yes
Mat'l Storage/Retrieval	10,596	317,880	Yes	Low	6 Mos	Yes	Yes
Mat'l Storage/Retrieval	2,219	66,570	No	Low	1 Mo	Yes	Yes
Parts Cleaning	12,687	380,610	Yes	Low	1-3 Mos	Yes	Yes
Grit Blasting	6,181	185,430	Yes	Low	6 Mos	Yes	No
Deburring/Finishing	883	26,490	Yes	Low	1 Mo	Yes	No
Painting	24,459	733,770	Yes	Low/Med	2-6 Mos	Yes	Yes
Ord Equip Repair	1,766	52,980	No	Med	3-6 Mos	No	Yes
Machining	2,649	79,470	No	High	2 Yrs	No	Yes
Tool Repair	883	26,490	No	High	2 Yrs	No	Yes
Material Maintenance	12,362	370,860	No	Low	3-6 Mos	No	Yes
Heat Treating	353	10,590	No	High	1 Yr	Yes	Yes
Totals	403,016	$12,090,480					

FIGURE 2
PRIME ROBOTICS APPLICATIONS
CHARLESTON NAVAL WEAPONS STATION
DOD DEPOT ROBOTICS WORKSHOP

ORDNANCE PROCESS	LABOR HR/YR	LABOR COST/YR	SPECIALIZED SKILLS REQ'D	HIGHLY REPETITIVE?	OTHER RELEVANT COMMENTS ABOUT PROCESS
Electrical Testing	25,678	$770,340	High	Yes	Process occurs in six shops which deal with missiles, mine torpedoes, MOSS, TMD, closures, and boosters
Disassembly	82,392	2,471,760	Med/High	Yes	Disassembly and assembly processes occur in eight shops dealing with missiles, mines, torpedoes, MOSS, TMD, closures, boosters, and conventional weapons. Includes many very short runs.
Assembly	96,630	2,898,900	Med/High	Yes	Dissassembly and assembly processes occur in eight shops dealing with missiles, mines, torpedoes, MOSS, TMD, closures, boosters, and conventional weapons. Includes many very short runs.
Material Handling	46,029	1,380,870	Low/Med	Yes	Process occurs in four buildings and throughout magazine area.
Packaging	43,739	1,312,170	Low/Med	Yes	Process occurs in eight locations.
Parts Cleaning	12,687	380,610	Low	Yes	Process occurs in six locations.
Painting	24,459	733,770	Low/Med	Yes	Process occurs in nine locations.

Figure 3
DETAILED PAINTING PROCESS ANALYSIS
CHARLESTON NAVAL WEAPONS STATION
DOD DEPOT ROBOTICS WORKSHOP



NAVY WEAPONS STATION PROCESSES

BY: ROBERT GUYMAN

PRESENTATION

Naval Weapons Station, Concord, California

MISSION	-	PROVIDE MATERIAL AND TECHNICAL SUPPORT FOR AMMUNITION/ASSIGNED WEAPONS
	-	MAINTAIN AND OPERATE AN EXPLOSIVE ORDNANCE OUT-LOADING/TRANSSHIPMENT FACILITY
FUNCTIONS	-	RECEIPT, SEGREGATION, STOWAGE, AND ISSUE OF AMMUNITION TO SUPPORT PACIFIC FLEET
	-	TRANSSHIPMENT OF DOD AMMUNITION
	-	RENOVATION AND EXTERIOR MAINTENANCE OF CONVENTIONAL AMMUNITION
	-	MISSILE INTERMEDIATE LEVEL MAINTENANCE
	-	SURVEILLANCE OF GUN AMMUNITION AND ASSIGNED MISSILE/MISSILE COMPONENTS
	-	DEPOT LEVEL REPAIR OF MISSILE CONTAINER AND HANDLING GEAR
POSSIBLE ROBOT APPLICATION	-	A MATERIALS HANDLING SYSTEM IN CONJUNCTION WITH AN X-RAY MACHINE AND REAL-TIME IMAGING SYSTEM

INDUSTRIAL OPERATIONS AND PROCESS AT THE NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA

BY: NORMAN QUINN

The Naval Weapons Support Center, Crane, Indiana is located in Southern Indiana, about one hundred miles southwest of Indianapolis. The assigned mission of this activity is to "provide material, technical and logistics support to the Navy for ships and crafts equipments, shipboard weapons systems and assigned expendable and non-expendable ordnance items: perform additional functions as directed by Commander, Naval Sea Systems Command."

At the present time there are 3160 civilian employees who work for the Navy at this activity. Approximately 2150 of these are General Schedule and the remainding 1010 are Wage Grade employees. The work force is a highly effective blend of professional, technical and hardware expertise.

Some of the major product lines which make up the current workload are:

- Microwave tubes
- FBM (Fleet Ballistic Missile) systems
- Electronic modules/devices
- Missile components
- Ships and subs equipment
- ASW (Anti-Submarine Warfare)
- Small Arms
- Batteries
- Pyrotechnics
- Conventional Ammunition

Figure 1 shows a process information matrix which provides a summary of some of the more labor intensive processes required to accomplish the mission of the activity. The list of processes is not all inclusive, but covers those which require expenditure of the most labor hours. It can be noted by the column on unit product volume that the volume of units produced ranges from low to moderate for most work involving the indicated processes. The range of different items/services provided is broad, but the volume of any one unit product is generally low.

Figure 2 provides a detailed analysis of an operation for the repair of .38 caliber revolvers. With considerable cost involved in assembly and disassembly, this operation is one which will be further investigated for future application of automation/robotics techniques.

INDUSTRIAL OPERATIONS AND PROCESS
AT THE NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA

In addition to small arms overhaul, other areas which have potential for future automation/robotics application are printed circuit board fabrication and material receiving/warehousing. There is an increasing amount of effort to develop techniques for automating the production and testing of printed circuit boards and other electronic modules. Some of these techniques will be considered for application at this activity. In the area of material receiving/warehousing, a study is being initiated to determine the feasibility of automation/robotics techniques, such as AS/RS and AWGS, to more efficiently accomplish this function. The key to implementing robotics systems at this activity depends to a great extent on how flexible a system can be designed to handle a variety of items which may differ slightly, but yet fit into a general family of items.

PROCESS INFORMATION MATRIX

PROCESS	TOUCH LABOR HRS/YR (K)	TOTAL COST/YR ($K)	HAZARDOUS/ UNPLEASANT WORK ENV.	UNIT PRODUCT VOLUME
ELECTRICAL TEST	71	2,130	NO	LOW
DISASSEMBLY	48	1,440	SOME	MOD
ASSEMBLY	141	4,230	SOME	MOD
MATERIAL HANDLING	66	1,980	NO	LOW-MOD
PACKAGING/PRES.	35	1,050	NO	MOD

FIGURE 1

DETAILED PROCESS ANALYSIS .38 CALIBER REVOLVER REPAIR

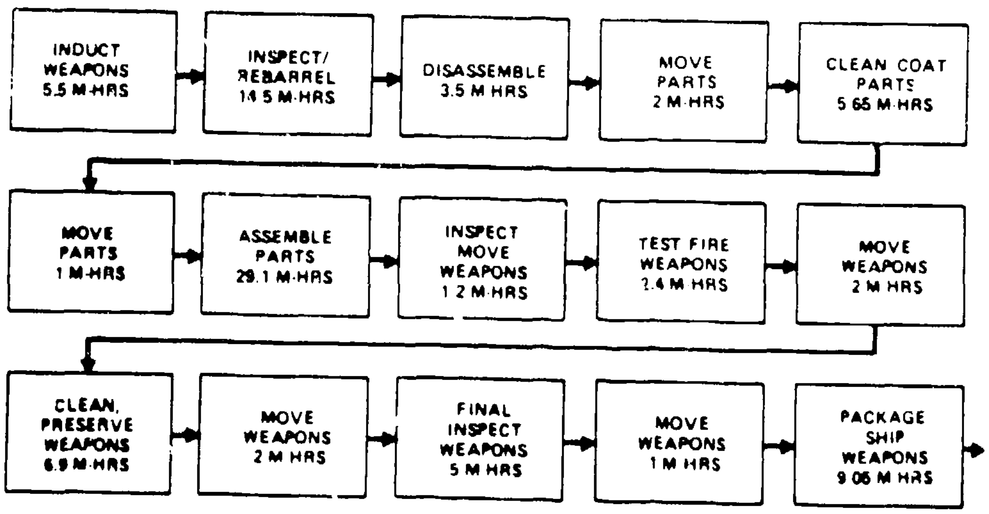


FIGURE 2

--ABSTRACT--

NAVAL WEAPONS STATIONS PROCESSES

By: Mike Travisano

NWS Earle

Earle is located in central New Jersey, with an ammo handling pier located 18 miles from the weapons station. Welding and metal cutting operations are a substantial operation at Earle, as are ammunition storage and issue and ammunition and container renovation. Potential applications for robotics include metal cutting and forming, packaging, parts cleaning, grit blasting, and painting.

In the container renovation operation, grit blasting, painting, restenciling, and materials handling were pinpointed by the speaker as potential volume production application areas for robotics.

--ABSTRACT--

NAVY ORDNANCE STATION PROCESSES

By: John Frick

NOS Indian Head

The Naval Ordnance Station at Indian Head provides technical support and production capability in explosives and ordnance propulsion systems and products, explosive devices (such as ejection seat cartridges), and weapons systems simulators. Typical manufacturing capabilities are such that production of small quantity specialty ordnance items and rework of same are the rule. The ordnance station acts as a second source on difficult to obtain items. Scale-up of developmental processes to production status is also done at Indian Head, as well as the preparation of tech data packages for industrial use in production.

The four major application areas for robotics at Indian Head are: (1) Material storage/handling (hazardous operations); (2) Air crew escape system components (where high quality/reproducibility are critical); (3) in cartridge-actuated device production (in assembly and inspection/test); and (4) in propellant mixing (a hazardous operation); volume production considerations do not apply at Indian Head, except in the material handling area.

ROBOTICS PROJECTS AND PROJECT PLANNING AT NUWES KEY PORT

NAVAL UNDERSEA WARFARE ENGINEERING STATION, KEYPORT
BY: JOHN BOGEN

HOT RUNNERS

- o Engine Breakdown
- o Dimensioning - QA
- o Cutting and Welding (SCEPS)
- o Harness Assembly
- o Canformal Coating
- o Component Board Stuffing
- o Chamber and Valve (Igniter)

* O-Ring Inspection System

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NAVAL UNDERSEA WARFARE ENGINEERING STATION
ROBOTICS PROJECTS

ROBOTICS PLANNING

- ESTABLISH ROBOTICS LABORATORY — JAN 1984
- ROBOT SYSTEM — UNIMATION PUMA 760, UNIVISION I
- FUTURE ROBOT SYSTEMS PLANNED

— MATERIAL LOADING (MACHINE SHOP)	1984
— AUTOMATIC OTTO FUELING (TORPEDO MK 46)	1984
— DEBURRING (MACHINE SHOP)	1985
— MOLD HANDLING (CABLE MANUFACTURING)	1985
— PARTS CLEANING (TORPEDO MK 46 & MK 48)	1985
— WELDING (DEPOT REPAIR)	1986

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NAVAL UNDERSEA WARFARE ENGINEERING STATION

ROBOTICS PROJECTS

DESIGN OBJECTIVES

- REMOVE WORKERS FROM HAZARDOUS ENVIRONMENT
- PROVIDE A RETURN ON INVESTMENT WITHIN 6 YEARS
- SPRAY TORPEDO SHELLS WITH A UNIFORM THICKNESS PRIMER & TOPCOAT
- AUTOMATICALLY PROPORTION, PUMP & MIX A TWO-PART POLYURETHANE PAINT
- INDEX THE SHELLS AUTOMATICALLY
- REDUCE SHELL HANDLING

NAVAL UNDERSEA WARFARE ENGINEERING STATION

ROBOTICS PROJECTS

OPERATING SYSTEM

- **ROBOT SYSTEM**
  - ROBOT - DeVILBISS 5 AXIS TRALLFA 3500
  - CONTROL - GOULD MICRO 84 COMPUTER
- **PAINT DELIVERY SYSTEM**
  - GRAYCO HYDRA-CAT PROPORTIONING PUMP
  - STATIC MIXER (MOUNTED ON ROBOT)
  - BOSTIK ALIPHATIC POLYURETHANE PAINT
- **CONVEYOR**
  - INDUSTRIAL TRACK WITH AUTOMATIC INDEXING
- **ECONOMIC ANALYSIS**

– TURNKEY COST	$270,000
– IMPROVED PAINT APPLICATION SPEED	30% FASTER
– REDUCTION IN REJECTION RATE	28% LESS
– ECONOMIC PAYBACK (CURRENTLY)	5 YEARS

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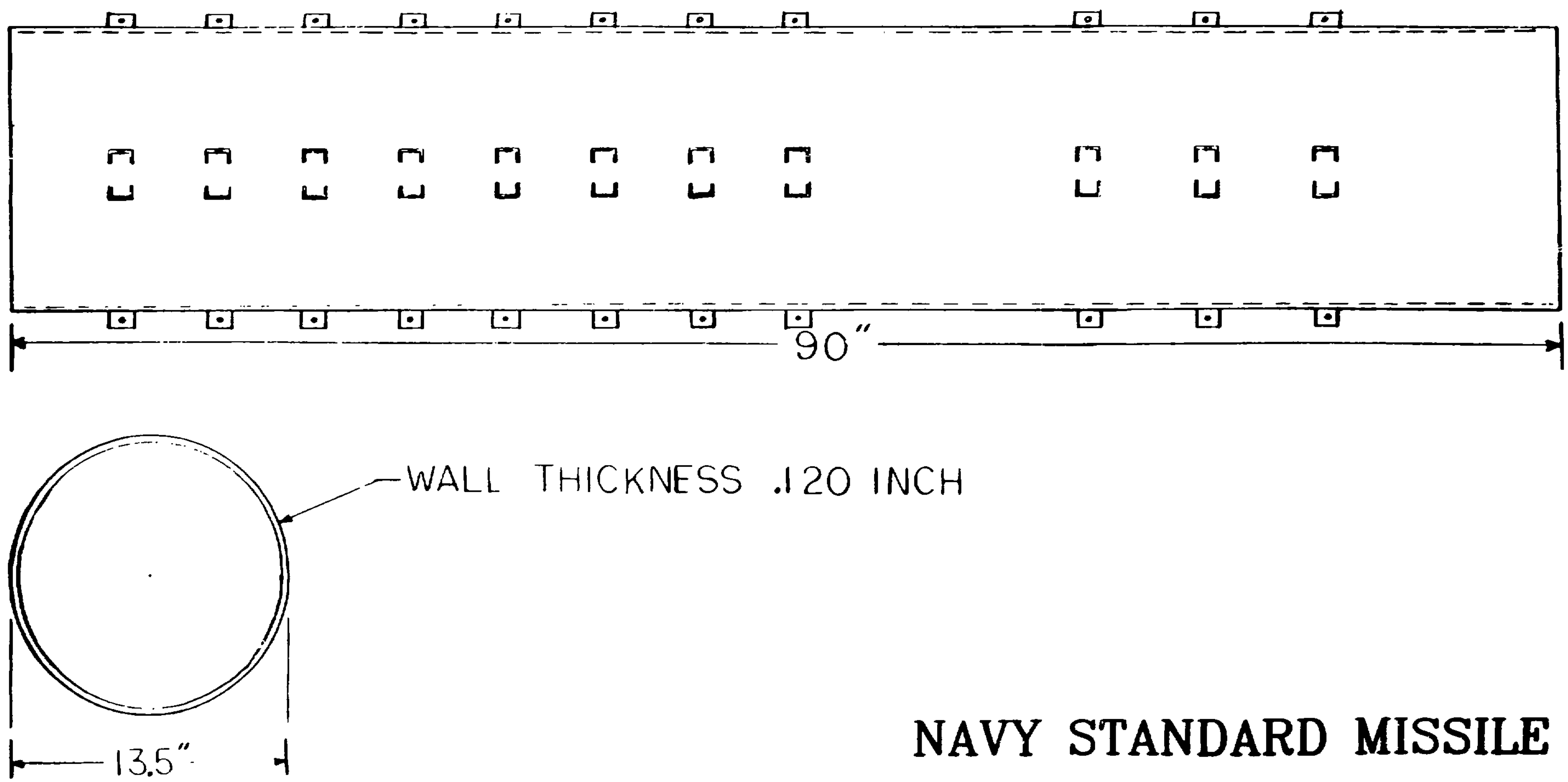
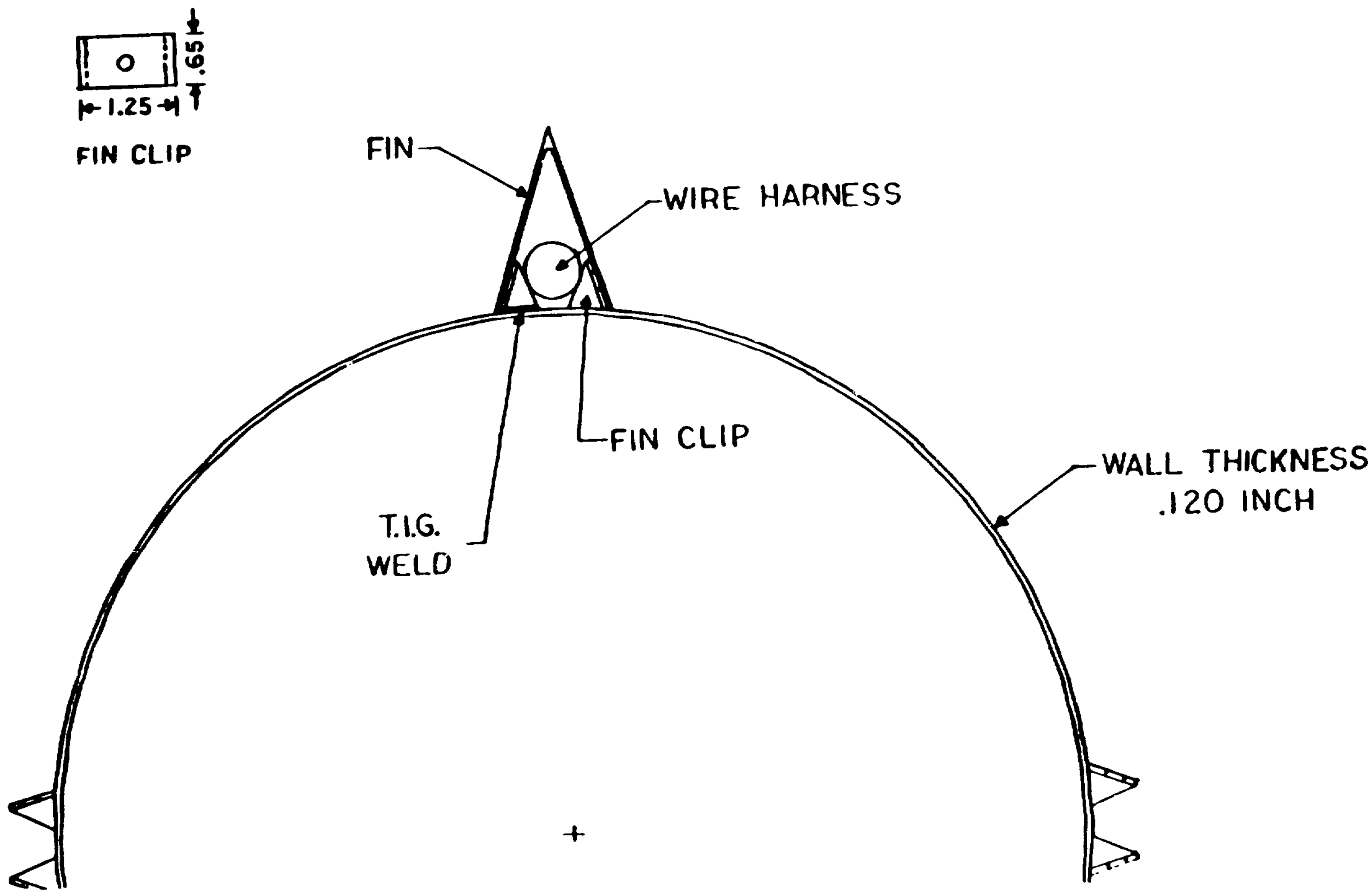
NAVY STANDARD MISSILE MOTOR MANUFACTURE
NAVAL ORDNANCE STATION, LOUISVILLE
BY: LARRY BELCHER



NAVY STANDARD MISSILE

MOTOR CHAMBER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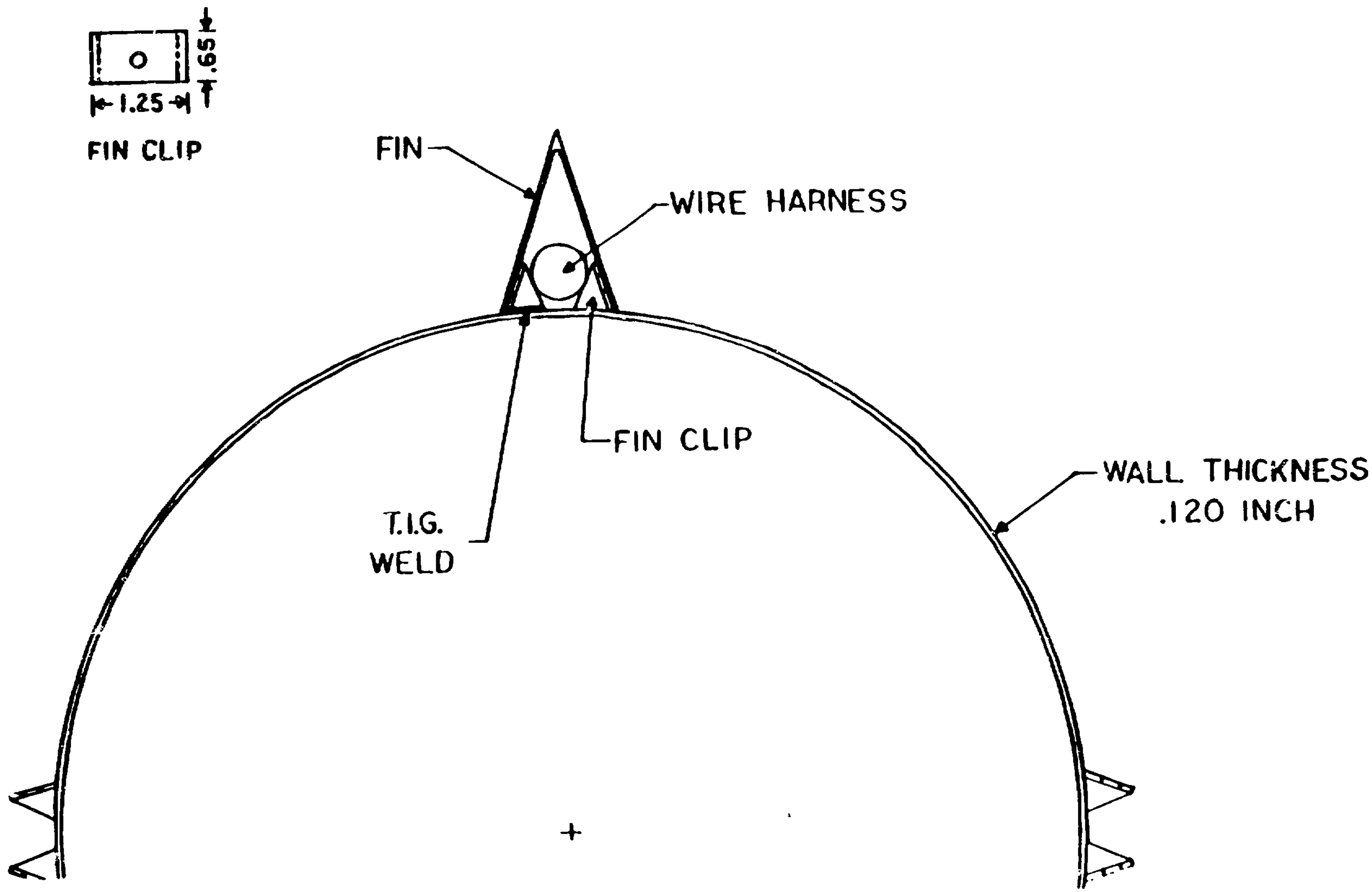
FIN CLIP
FIN
WIRE HARNESS
FIN CLIP
WALL THICKNESS
.120 INCH
T.I.G.
WELD



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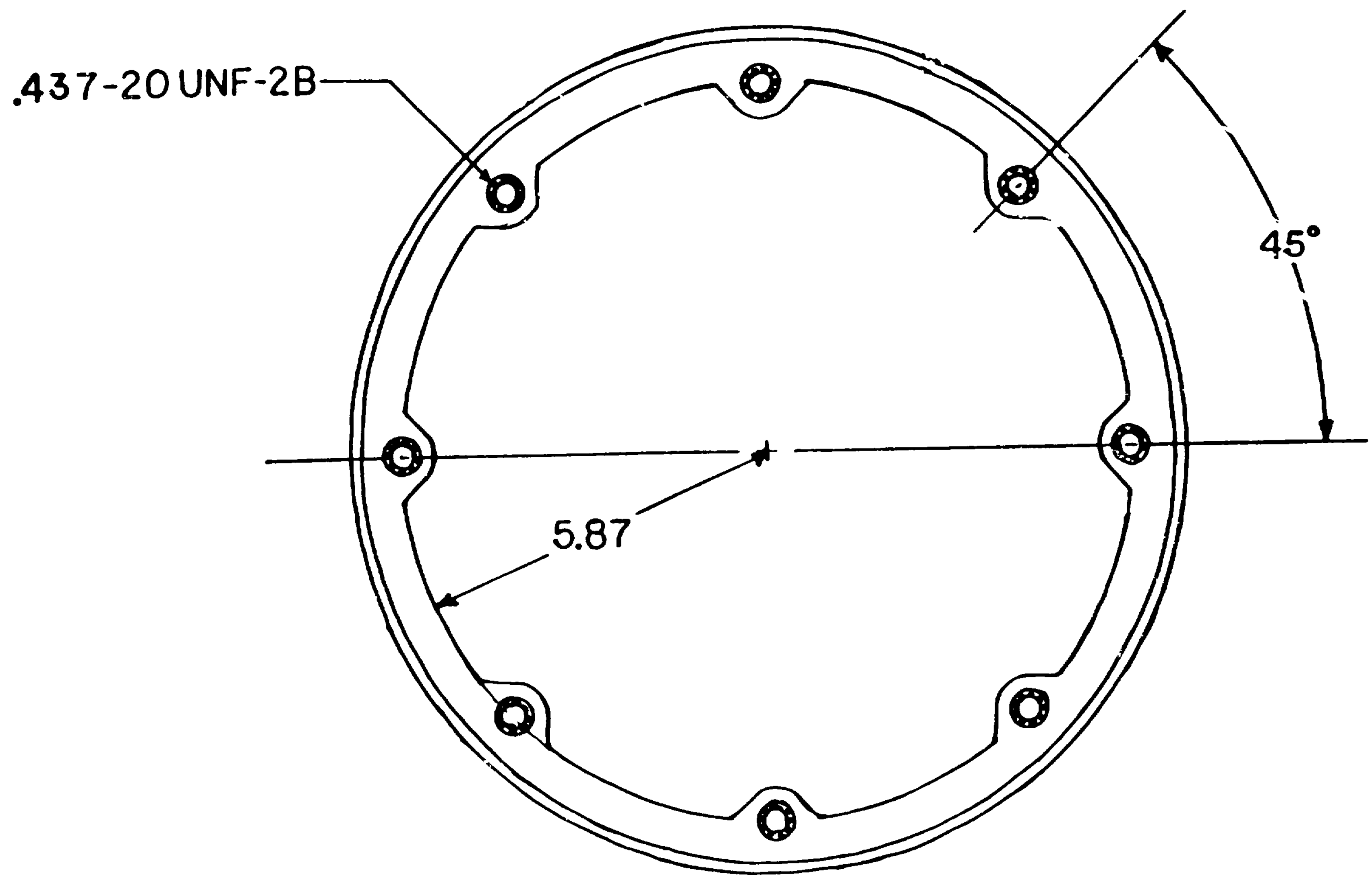


FORWARD ENCLOSURE

NAVY STANDARD MISSILE

MOTOR CHAMBER

PROCESS CHART

* Denotes touch labor operations.

Hydrospin Operation

↓

four times

↓

Heat treat to anneal.

↓

* Sand blast and clean.

↓

Cut motor to length and prepare for welding.

↓

Weld forward and aft enclosures to motor chamber.

↓

Drill, ream, and tap holes forward enclosure.

↓

* Weld fin clips to motor chamber.

↓

Heat treat motor to stress relief.

↓

Drill, spotface, and tap holes in motor.

↓

Mill keyways and bayonet openings aft enclosure.

↓

Drill holes in fin clips.

* Fin clip pull test.

* Inspect for cracks and machine tolerances.

* Plate chamber motor.

* Mask and prime.

* Prepare for shipping.

NAVY STANDARD MISSILE MOTOR CHAMBER

* Denotes touch labor operations.

1. A forging is rolled on the Hydrospin machine in five separate operations to form a rocket motor chamber with no seams or weak spots. (Enclosures 1 & 2) Motor chamber is routed through a heat treating process between each spin operation to anneal forging.

2. Motor chamber is routed through the sand blast machine and cleaned in preparation for the machining and welding processes.

3. A turret lathe is used to cut the motor chamber to the proper length, face the ends of the motor, bore holes and turn down ends in preparation for welding the forward and aft enclosures to chamber. (Enclosure 3)

4. Preheat motor chamber to 400 degrees F. and weld forward and aft enclosures to motor chamber using seven continuous welding passes on each end. Weld is then checked for full penetration. (Enclosure 4)

5. After mounting motor on a drill fixture, drill, ream and tap autopilot mounting holes in forward enclosure. Holes are gaged as they are tapped. (Enclosure 5)

* 6. Preheat motor chamber to 400 degrees F. on calrod heater fixture. Load double row of fin clips in fixture. (Enclosure 6). T.I.G. weld clips to motor 34 places per double row. Index motor 90 degrees and repeat until all four double rows of clips are welded to motor. Fin clips must be positioned within .030 inch from the front of the motor to fin clip location on each clip dimension. Face of fin clips must align within .015 inch from end clip to end clip. (Enclosures 7)

7. Chamber motor is then heat treated to stress relief all weld joints.

8. Install chamber motor on a fixture for machining. Drill, ream, and tap all remaining holes in forward enclosure. Mill keyways and bayonet openings on inside surface of aft enclosure. (Enclosure 8)

9. Install chamber motor into drill fixture. Drill 1/4 inch hole in the center of each fin clip face and deburr holes. (Enclosure 9)

* 10. Fin clip welds are strength tested by applying 1150 pounds of pressure pull on each clip. (Enclosure 10) Motor chamber is hydrotested to 3000 pounds per square inch to test weld and stress points for cracks. (Enclosure 11)

* 11. Chamber motor is magnetic particle inspected for cracks in weld joints and for machining to print tolerances.

* 12. Chamber motor is cleaned and Zinc phosphate coated.

* 13. Mask, epoxy prime, bake at 200 degrees F. and unmask chamber motor. Inspect to make sure epoxy primer has cured. (Enclosure 12)

* 14. Chamber motor is cleaned and prepared for shipment.

ECONOMIC SIGNIFICANCE

ROCKET MOTOR CHAMBER ASSEMBLY

78.26	Manhours per motor - Present Method
-58.99	Manhours per motor - Proposed Method (est.)
19.27	Manhour Savings per motor (est.)
x 1080	motors per year
20,811.6	Total manhours saved per year (est.)
x $17.38	accelerated labor rate
$361,705.61	Total Savings per year

Savings projected on standard missile MK 56 rocket motor only. Process could possibly be expanded to manufacture other rocket motors at station such as the ASROC motor.

NAVY WEAPONS STATION PROCESSES
NAVAL WEAPONS STATION, SEAL BEACH
BY: WILLIAM KOOP

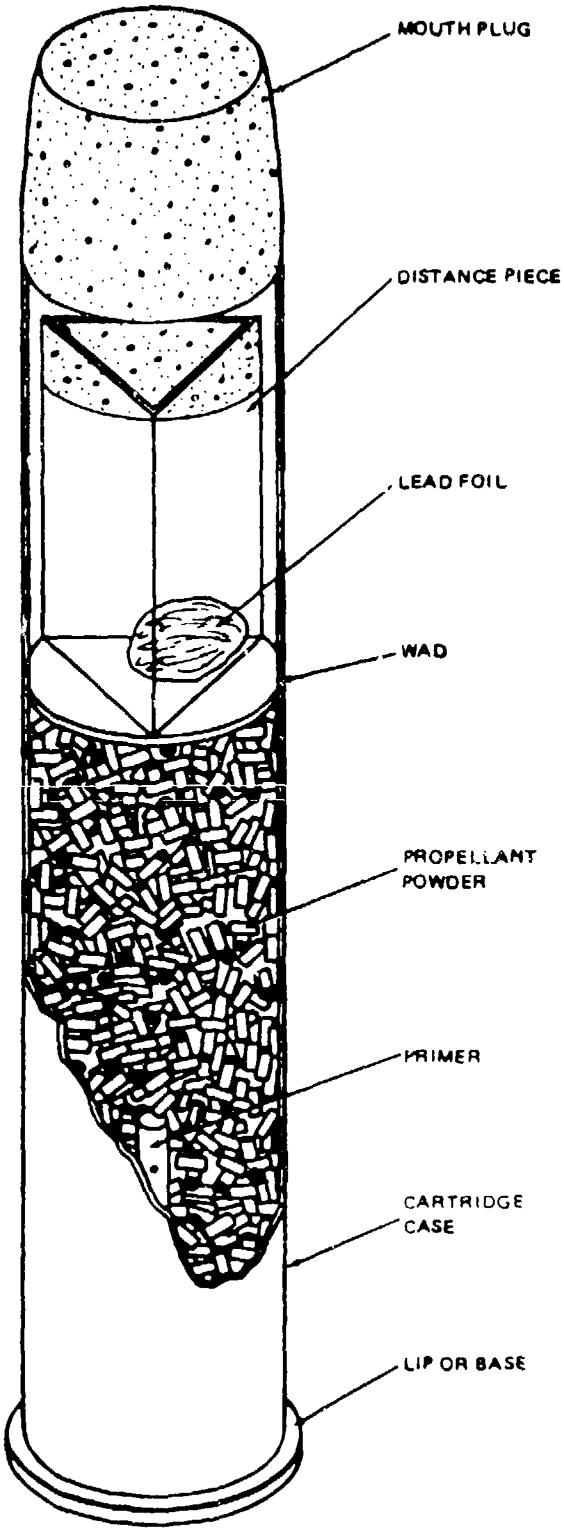


Figure 2-5. Components of the Propelling Charge in Separated Ammunition

	VOLUME / LOT SIZE	PRECISION	PERSONAL PROTECTIVE EQUIPMENT	REPITITION	HAZARDOUS MATERIAL INVOLVED	EXTENT OF APPLICATION	CRITICAL OPERATION	
PAINT	MED	MED	YES	MED	LOW	100 %	NO	
CLEAN	MED	LOW	YES	MED	HIGH	100 %	YES	
PALLETIZE	MED	MED	YES	HIGH	MED	HIGH	NO	
FUZE SETTING	MED	HIGH	YES	HIGH	MED	LIMITED	NO	
STENCILING	MED	MED	YES	HIGH	LOW	100 %	YES	
GAUGING	MED	HIGH	YES	HIGH	LOW	HIGH	YES	
INSPECTION	MED	MED	YES	HIGH	LOW	100 %	YES	
SEGREGATION	HIGH	HIGH	YES	HIGH/ VARIABLE	HIGH	LIMITED	NO	
MATERIAL HANDLING	MED	MED	YES	HIGH	MED	100 %	NO	
TESTING	MED	HIGH	YES	HIGH/ VARIABLE	MED	LIMITED	YES	
SANDBLASTING	MED	MED	YES	MED	HIGH	LIMITED	NO	

	3 INCH PROJECTILE	5 INCH PROJECTILE	16 INCH PROJECTILE	5 INCH PROPELLING CHARGE	16 INCH PROPELLING CHARGE	TANKS	SURFACE MISSILES	MISSILE CONTAINERS
PAINT	x	x	x	x	x	x	x	x
CLEAN	x	x	x	x	x	x	x	x
PALLETIZE	x	x	x	x		x		
FUZE SETTING	x	x						
STENCILING	x	x	x	x	x	x	x	x
GAUGING	x	x	x	x	x		x	
INSPECTION	x	x	x	x		x	x	x
SEGREGATION	x	x	x	x	x			
MATERIAL HANDLING	x	x	x	x	x	x	x	x
TESTING							x	
SANDBLASTING	x	x						x

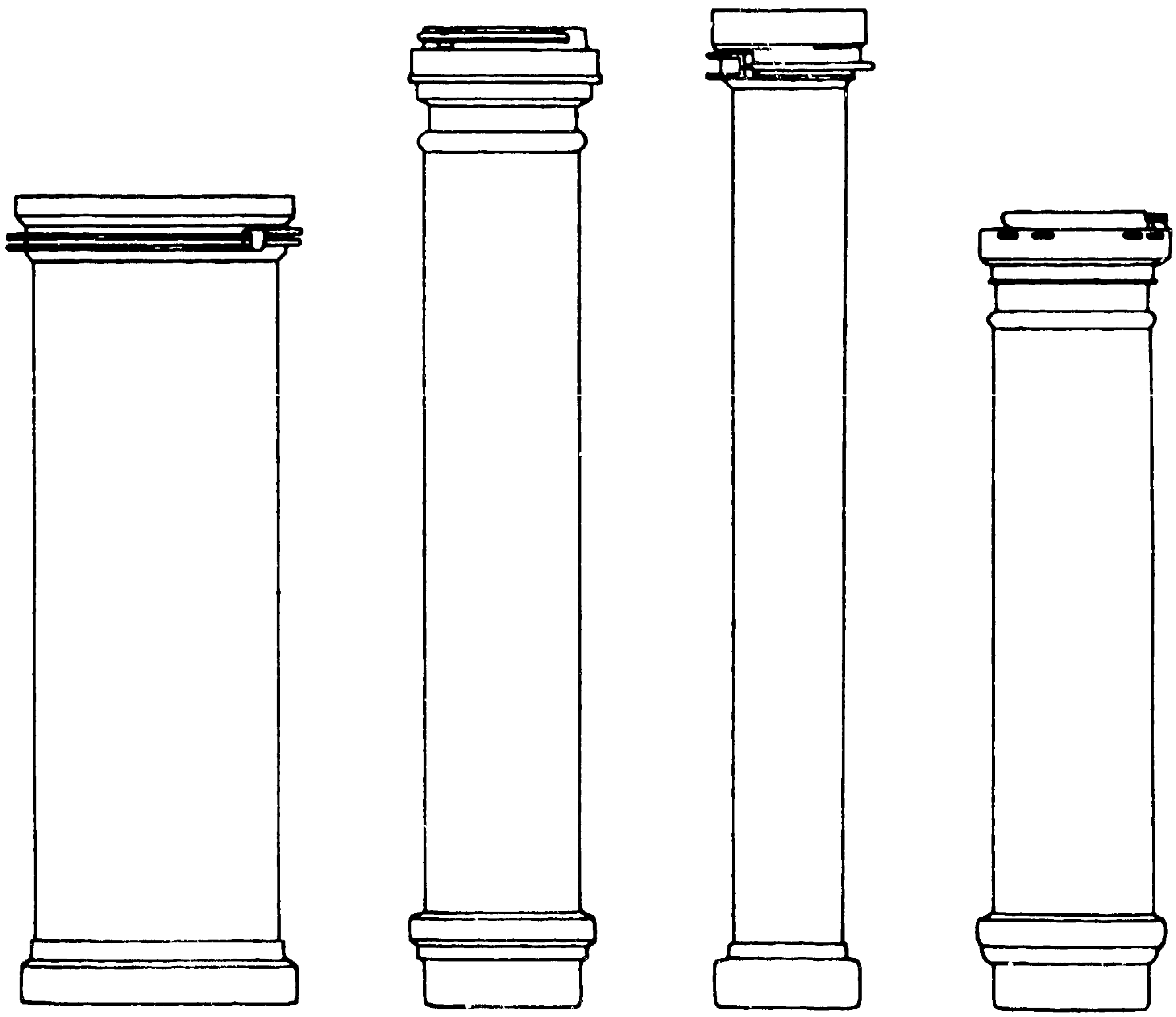
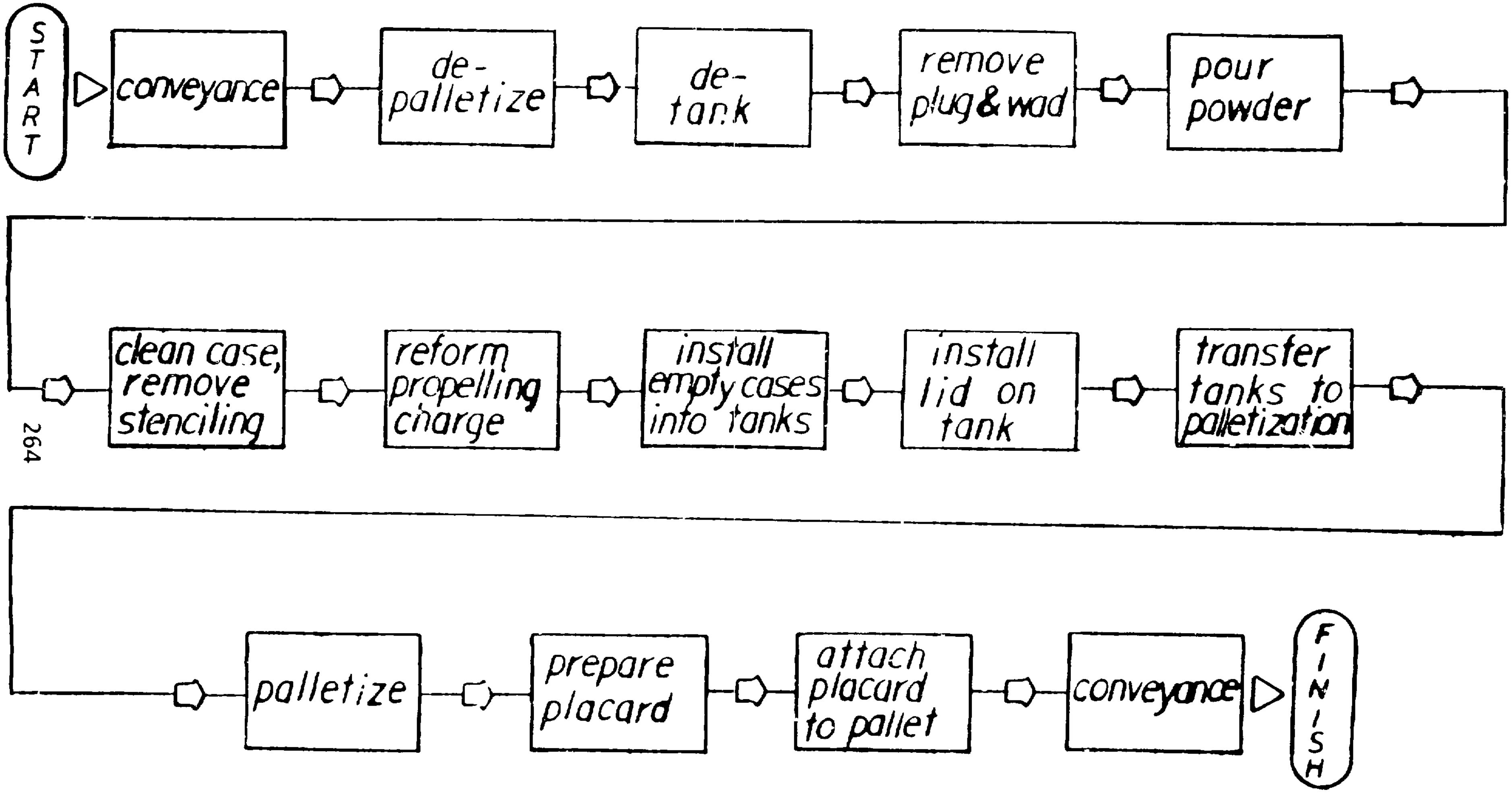


Figure 2-12. Typical Tank-Type Containers. (Left to Right) 8-Inch Bagged Charge; 5-Inch, 54-Caliber Cartridge; 3-Inch, 50-Caliber Cartridge; and 5-Inch, 38-Caliber Cartridge

5 INCH/54 CAL.
PROPELLING CHARGES BREAKDOWN FOR REASSEMBLY



WEAPONS STATION PROCESSES

NAVAL WEAPONS STATION YORKTOWN VIRGINIA

BY: DAVE HEAPE

PROCESS	TOUCH LABOR HRS/YR	TOTAL COST/YR	HAZARDOUS/ UNPLEASANT WORK ENV.	LABOR SKILL REQUIRED	JOB TRAINING	KEP OPN's COMMOM TO OTHER PROCESSES
EXPLOSIVE LOADING	41,600	1,874,000	YES	MOD	6 MO.	YES
RENOVATION	67,500	2,224,000	YES	MOD	6 MO.	YES
LEVEL I INSPECTION	22,900	768,700	YES	LOW	6 MO. OJT	YES
WELDING	CUSTOM APPLICATION MAINTENANCE OPERATIONS	N/A	YES	HIGH	2 YR.	NO
METAL CUTTING/ FORMING	CUSTOM APPLICATIONS MAINTENANCE OPERATIONS	N/A	YES	MOD HIGH	4 YR.	NO
COMPONENT TESTING	N/A	N/A	NO	HIGH	2 YR. OJT	NO
MATERIAL HANDLING MOVEMENT/STORAGE	N/A	N/A	YES/NO	LOW	3-6 MO. OJT	NO
PACKAGING PRESERVATION	CUSTOM APPLICATIONS LOW VOLUME	N/A	NO	LOW	3-6 MO. OJT	NO
METAL MACHINING OPERATION	CUSTOM APPLICATION	N/A	YES	HIGH	2-4 YR.	NO
TOTAL	132,000	4,866,700				

* MATERIAL HANDLING NOT CONSIDERED DUE TO THE DIVERSIFICATION AND TYPE OF HANDLING. APPLICATION OF AUTOMATED STORAGE AND RETRIEVAL SYSTEMS OF LIMITED ITEMS CAN BE CONSIDERED, BUT WORK IS NOT SUITABLE TO ROBOTIC APPLICATION.

AD-P004 003

JET ENGINE BLADE REPAIR

OKLAHOMA AIR LOGISTICS CENTER, PROPULSION DIVISION
OC-ALC/MAE

BY: MAURICE LEBLANC

INTRODUCTION:

Today I would like to acquaint you with the facilities and processes which are required to overahaul jet engine blades at the Oklahoma City Air Logistics Center. While the presentation is based on the operations at the Oklahoma City ALC, a similar repair capability also exists at the San Antonio Air Logistics Center.

In recent years, jet engine blade repair has become an increasingly important part of our overhaul requirements. Cost factors and availability of materials have resulted in repair processes being implemented to salvage blades which, in past years, would have been condemned.

the resources expended on blade repair is currently a significant amount. Our projections indicate future expenditures will increase with the workload volume. this fact has made blade rework a prime area for implementing several projects to increase productivity and to make the repair process more cost effective.

BLADE WORKLOAD

Volume:

	FY81	FY83	FY85
Engines Per Year	1,137	1,220	1,438
Compressor Blades	1,494,380	2,776,850	3,629,490
Turbine Blades	355,410	478,720	625,710
Total Blades	1,849,790	3,255,570	4,255,200

Expenditures: (FY83)

New Buys	$ 110,352.00
Repair	34,319,000
Total Blade Investments	$144,671.000

Blade repair requirements can vary from a simple operation, involving go-no go inspection criteria for acceptance or condemnation, to rather complex procedures involving a multitude of inspection and repair processes. The repair scheme can range from a one time opeation to sequence involving multiple recycles. Because of the characteristic differences between compressor and turbine blades, I will discuss typical processes and operations rather than the detailed flow (See chart #1) of a blade through the repair cycle.

Inspection of the blades condition actually begins at disassembly. Defective blades are condemned prior to entering the repair process. (See photograph #1)

Blades are secured in disks by special tablocks or rivets which causes blade removal to be a labor intensive process. A special machine with dedicated tooling is used to straighten tablocks and the blades and tabs are then driven out of the disk using a brass drift and hammer. Blades secured by rivets are removed with a punch and hammer. Because of the interlocking feature found on some turbine blade shrouds, blades must be driven out in small increments working around the disk with a mallet.

After the blades are placed in special wire baskets, they can be transported to any of several required cleaning processes including chemical cleaning, blast cleaning individual blades using a wet or dry media, and vibratory cleaning using various abrasive media. The vibratory machines are also used to obtain smoother blade surface finishes prior to engine assembly.

Blades are ready now for a thorough inspection by a variety of methods. Visual and dimensional inspections are used to detect obvious defects, determine time codes, and separate blades by process categorization. Visual inspections using 10 and 30 power magnifiers are done to detect cracks in critical areas. Fluorescent penetrant/black light inspection and magnetic particle inspection are also used, depending upon the specific blade requirements.

Some of the more complex blades such as the TF30 fan blade use ultrasonic and eddy current to inspect critical areas. These inspections determine the extent of blade damage, eliminate condemnable blades (To avoid unnecessary processing), and establish the required repair criteria for repairable blades.

The inital repair process for compressor blades involves using powered grinders, buffers, and sanders to hand blend leading and trailing edges. Continual inspection is required during this stage to assure the blade dimensions and radius limits are maintained within technical order specifications.

After surfacing is completed, blade strength in high stress areas is enhanced by using steel ,shot and glass bead peening techniques on the blade root area.

After prior surface preparation by dry blasting, some items, such as J79 blades and vanes, are installed in condemned disks or special fixtures, and masked. (See photograph #2)

A protective coating of Sermetel-W paint is applied to provide the corrosion protection which will be required at the engines operating environment. After baking the paint in a 650^{O}F oven, an antigaulling component is spray painted on the blade root areas to reduce seizing between the blade root and the disk.

Because of availability of materials and the prices of new blades, turbine blade repair is an important and major portion of our workload. It also involves the most sophisticated and demanding blade repair processes.

Turbine blades are dimensionally inspected using precision gauges to determines worn areas, such as airseal heights at the blade tip.

Those areas not meeting imum dimensional requirements, such as the blade shroud notch areas, are manually welded. In addition to rebuilding worn surfaces, special areas which have been ground out to eliminate radial cracks, are filled prior to the precision grinding operation. (See photograph #3)

Blades are sent through a heat treat cycle in argon atmosphere vacuum furnaces to relieve welding induced stresses.

Prior to grinding, blades are checked for proper twist angles, and then ground to specified dimensions using electro-chemical grinders.

Electrochemical grinders have replaced conventional grinders because of their ability to produce a better quality grind and the elimination of heat induced cracks which previously occured during the conventional grinding process.

After post-grinding inspections, the final step in the blade repair cycle consists of mass weighing individual blades on electronic scales or moment weighing the blades using precision electronic balances.

The blades are paired by equal weight values, assembled into blade sets, and sent to the engine subassembly areas where they are installed in compressor or turbine disks.

At the beginning of this presentation, I mentioned several projects are being implemented, or are being studied, to improve both the cost effectiveness and the productivity of the blade rep process. The projects encompass both facilities and equipment.

BLADE REWORK
TECHNOLOGY/MODERNIZATION PROJECTS

* Facilities
* Disassembly
* Inspection (NDI)
* Measurement
* Welding/Grinding
* Paint/Burnish

Currently, blade repair is being more difficult in our existing facility because blades must be transported between widely separated work areas for processing. We are working with the Corp of Engineers to implement a FY85 Military Construction Program for a new building dedicated to blade repair. The project will consist of a 125,000 square foot building which will consolidate the blade rework functions and will house, in addition to conventional repair processes, several automation and technology projects. The building will utilize a supervisory computer which will monitor the mechanized material handling system, provide real-time parts tracking for inventory control and scheduling, generate management reports, provide workloading of various processing cells, and monitor the status of the automated equipment cells.

Another area for productivity improvements is the blade/disk disassembly process. Savings are expected by decreasing the labor intensiveness of the work and reducing inadvertent damage to blades and disks which results from the "Brute Force" method of disassembly we must currently use.

A feasibility and concept development study has been completed, by the Battelle Laboratories Columbus, Ohio, to automate the disassembly process. Based upon preliminary data, the project's potential for cost savings and success are sufficient enough to warrant further development. This project is being monitored by the Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio.

The initial effort to improve the non-destructive inspection (NDI) process is to improve upon the manual transporting and processing currently required for fluorescent penetrant inspection.

A FY85 project is being planned to install an automated fluorescent penetrant application system. This system will be a follow-on project made possible by transferring the technology of a similar unit which has been installed at the San Antonio Air Logistics Center.

The system will have a Process Controller to monitor throughput rates, material application, dwell times, and other parameters. Electrostatic application of both penetrants and developing media will reduce material consumption as well as provide a more consistant quality product for inspection.

Another NDI project being considered for implementation is the automation of the Visual and Fluorescent Penetrant Inspection Processes. A system consisting of visual and fluorescent penetrant inspection modules, computer controller, and associated materials handling equipment is currently being evaluated at the San Antonio Air Logistics Center. Our decision to implement a similar system will ultimately be based upon the Integrated Blade Inspection System (IBIS) performance in a production environment as well as the cost effectiveness based upon our particular production requirements.

Currently, numerous manual dimsensional measurements and inspections are required at all stages of the blade repair process.

Because of the large volume of blades which are processed annually, Automated Blade Measurement is another project being considered for implementation. A preliminary study has been completed and the cost effectiveness of the system will be evaluated before a decision is made to proceed with further development.

The Automated Blade Measurement System would be comprised of two basic modules. the first module (Shroud and Airfoil Measurement Module-SAFMM) would use precision laser, optical, or video technology to measure dimensions such as blade length, airseal heights, notch and shroud wear, blending radii, and other dimensional parameters.

The second module (Measure and Adjust Rotation Module MARM) would measure the degree of twist in a turbine blade, identify out of limit blades, and adjust the rotation as required to restore the blade to allowable limits. Both modules would be designed to integrate with the Integrated Welding and Grinding (IWAG) equipment. The data transfer would give the IWAG System the capability to perform variable weld/grind operations and automatically adjust the system to compensate for deviations in the weld/grind feedback cycle.

The most important area of process automation we are currently implementing will be the blade welding and grinding operations. Under the ausprices of the Air Force Wright Aeronautical Laboratories at Wright-Patterson AFB, Ohio a Manufacturing Technology Project was established to automate both processes.

Equipment is being developed by the Battelle Laboratories, Columbus, Ohio, and selected subscontractors, which will form an Integrated Welding and Grinding (IWAG) cell. The initial IWAG demonstration cell equipment is scheduled to be installed at Oklahoma City ALC in March 1984. (See photograph #4)

The major items of the IWAG Demonstration Cell will be an Automated Welding Module consisting of a welder, process controller, queuing station, and an industrial robot for parts transfer and machine loading/unloading. The robot (Model P300V) is being supplied by the GCA/PAR Company. (See photograph #5)

The welder has been built by CRC Welding Systems of Nashville, Tennessee. The machine is an automated, two station, multiaxis welder capable of plasma arc welding all shroud, notch and airseal surfaces at a rate of 45 blades/hour. This equipment is presently undergoing prototype at Battelle. (See photograph #6)

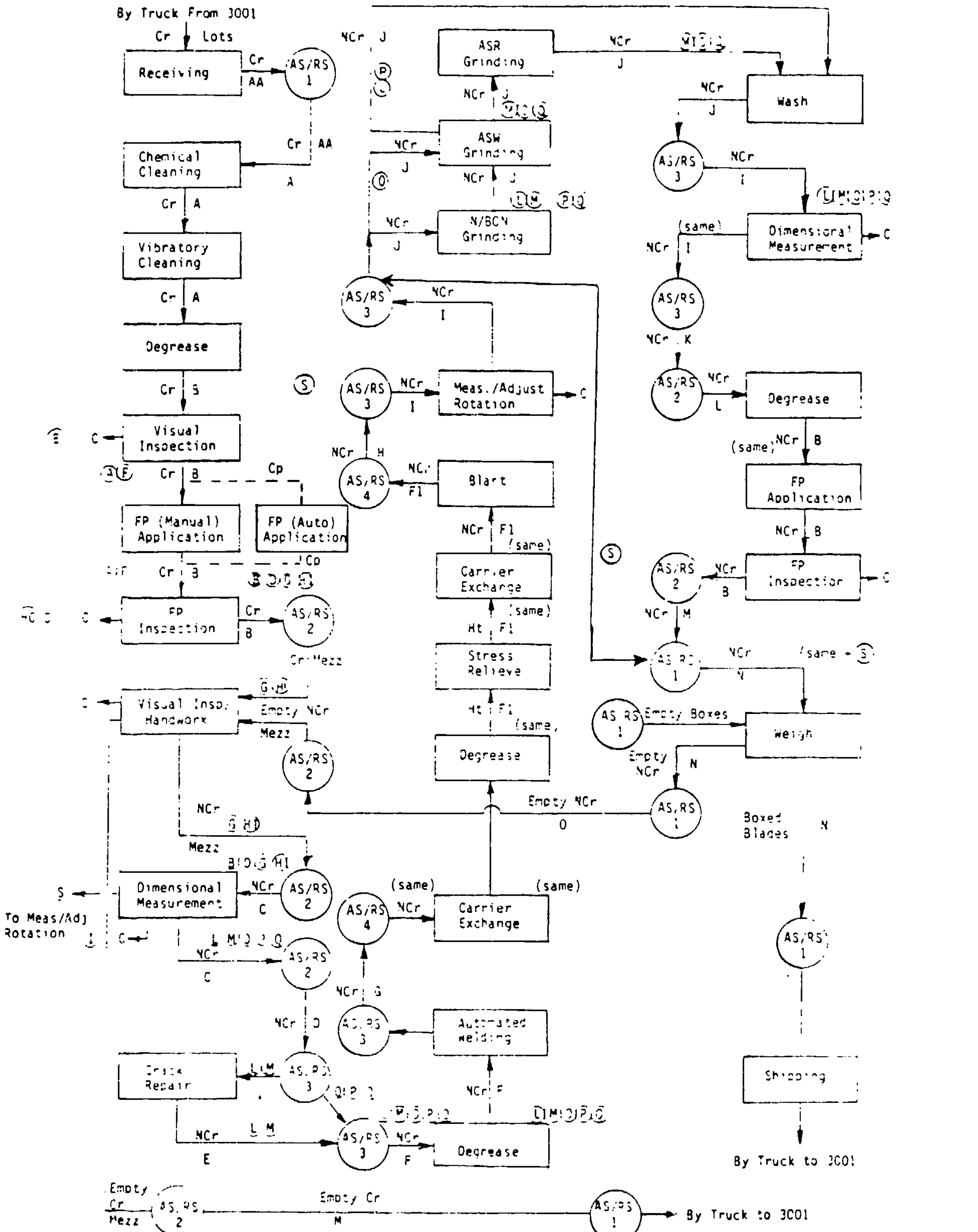
The grinding module will have the same ancillary equipment as the welding module. Three types of grinders will be used to grind blade notches, airseal widths, and the airseal height/radius. The equipment will be an electrolytic grinder with two load/unload stations and two grind stations. The grinder will use precision centerline fixturing on an indexing table and has a design rate of approximately 180 blades/hour. The grinder components are presently being assembled at the manufacturer's plant (Anocut, Inc., Chicago ILL). When assembly and functional tests are completed, the units will be sent to Battelle for prototype testing and system integration. (See photograph #7)

The final topic I will discuss today is the manual application of Sermetal - W Paint, baking, and burnishing of blades. This is a prime area for process improvement because of the labor required and the projected increase in J79 engines which will be refurnished.

We are currently evaluating proposals to award a contract for an automated blade and vane processing module. This system will have computer controllers to monitor transportation of blades and vanes through the system as well as process automation for surface preparation, painting, baking, and final burnishing of the painted surfaces. The controllers will also monitor operational parameters such as air pressures, paint levels, oven temperatures, bake times, and other critical factors to assure consistent product quality, greater uniformity of application, and improved material usage. The system will have the capacity to process 8,000 blades or vanes per 8 hour.

Conclusion:

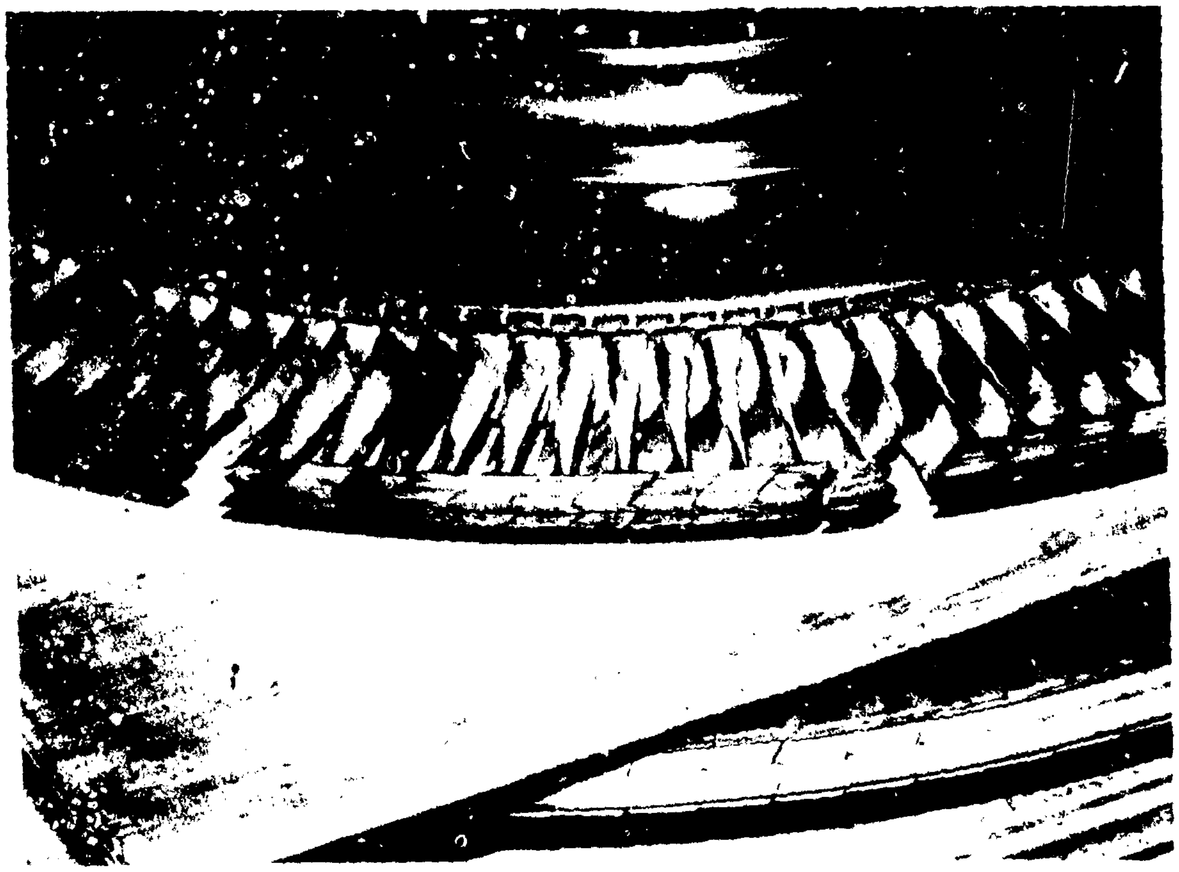
The preceeding projects, which I have discussed today, represent the first step in a continuing effort to use technology for economical solutions which can improve manufacturing processes. The development of IWAG and other automated systems, at Oklahoma City and other bases, represents a significant commitment by the Air Force to improve their Industrial Base and Productivity through the application of existing state-of-the-art technology.



F1 = Transport at floor level
Cp = Clip
Cr = Present Basket
NCr = Nested Carrier
Ht = Heat Treat Carrier
C = Condemn

ATTACHMENT 20. HIGH LEVEL PROCESS FLOW DIAGRAM FOR TURBINE BLADES

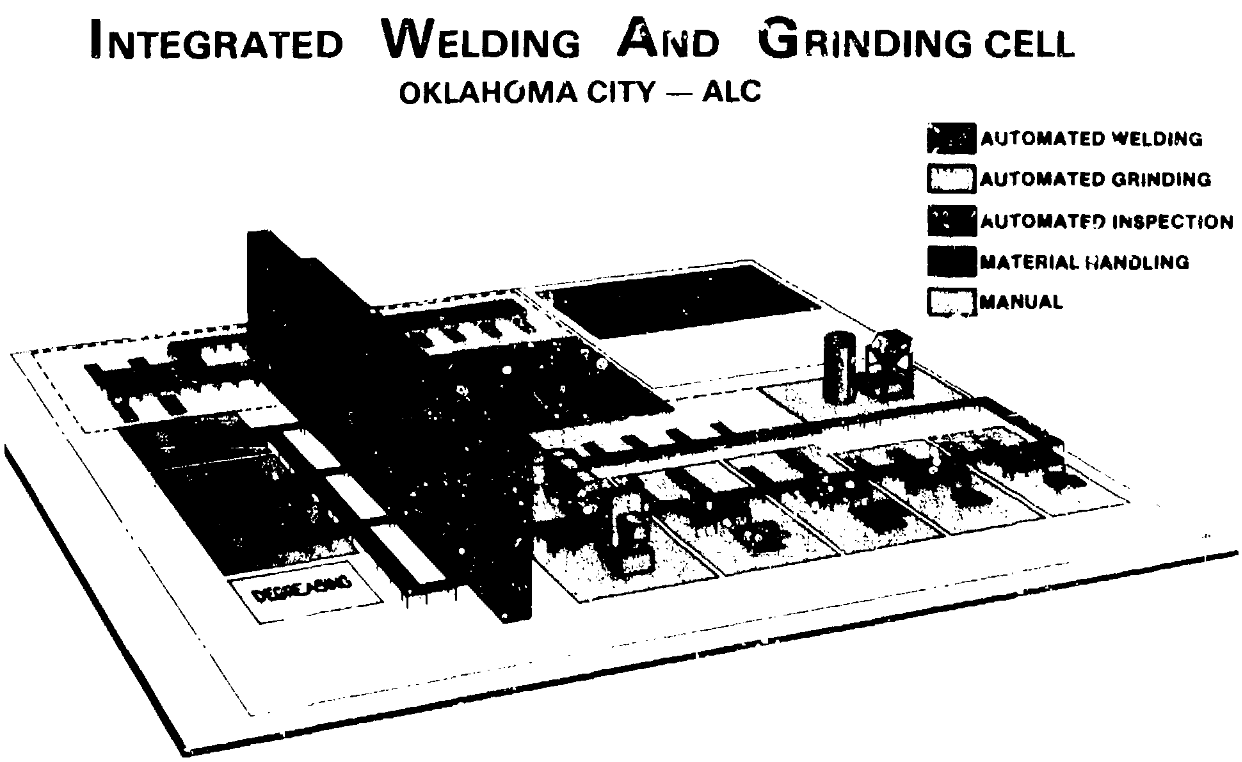
A = No visual flaws
B = No visual flaws, no crack flaws
D = No visuals, crack condemn
E = No visuals, cracks



Photograph #1

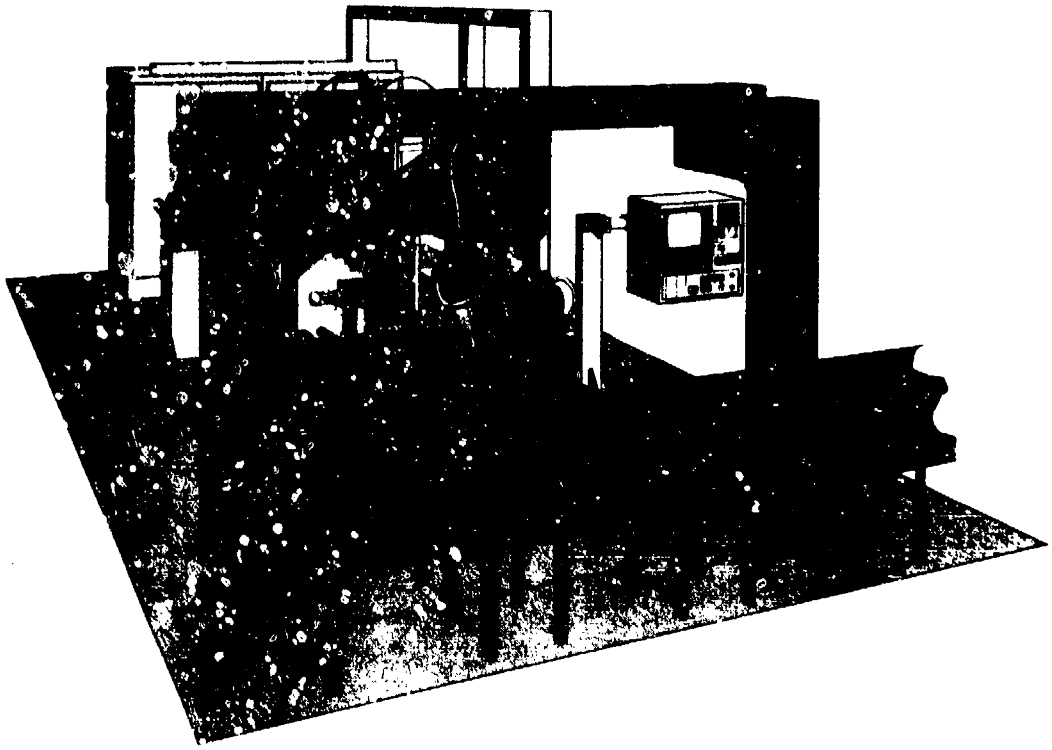
Photograph #2

Photograph #3



Photograph #4

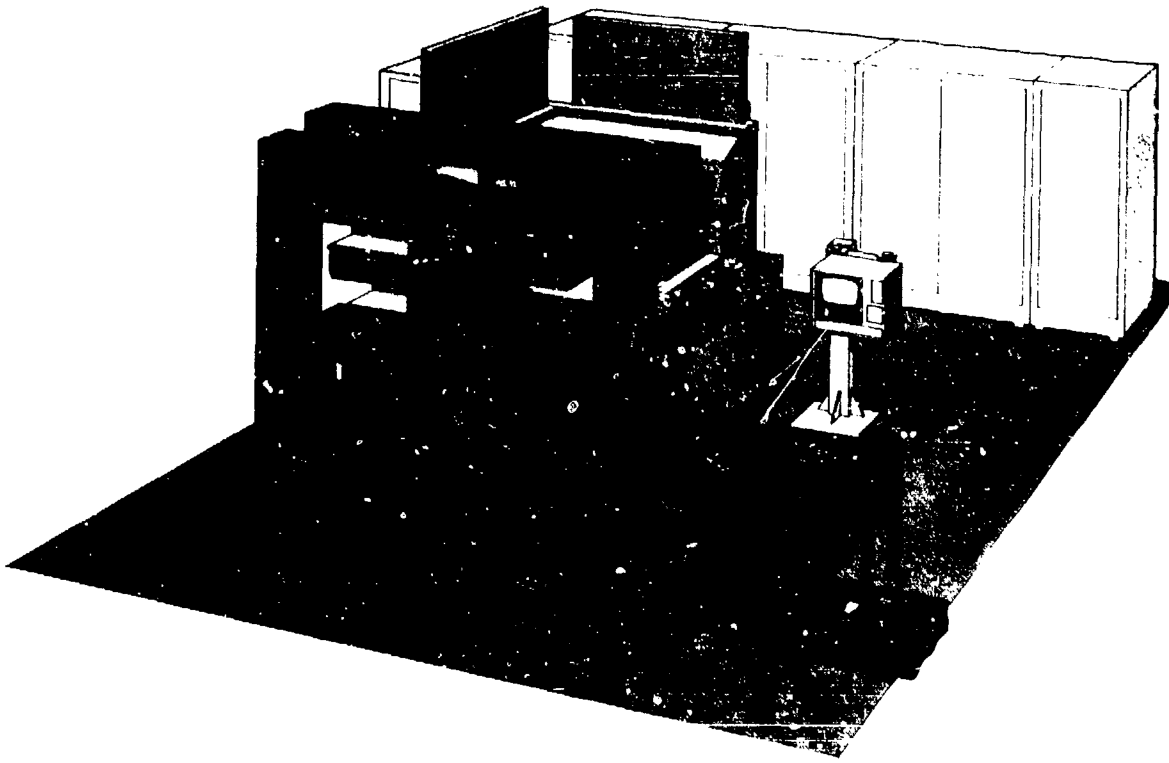
AUTOMATED WELDING MODULE
IWAC CELL



Photograph #5

Photograph #6

AUTOMATED GRINDING MODULE
IWAG CELL



Photograph #7

AIR FORCE PLASMA SPRAY AT SA-ALC

-WRIGHT-PATTERSON AIR FORCE BASE-
AFWAL/MLTM

BY: S. LEE

Commercially available computerized thermal spray equipment is basically limited in scope. These units only address the application of coatings and are not system oriented. Surface preparation, masking, and precoating as well as post coating parts handling operations are not addressed from an integrated manufacturing cell perspective. The challenge in the ~~this~~ Manufacturing Technology (MT) program is to improve productivity and minimize operator safety hazards by establishing an integrated computerized thermal spray cell that encompasses automated surface preparation, process control, part manipulation and spray gun control. The automated systems must be flexible and adaptable to changes in work load requirements and part configuration. The automated plasma spray cell is the first building block for eventual establishment of a thermal spray processing center that will include flame spray, wire spray and possibly vacuum plasma spray cells. Many operations such as parts handling, pre/post coating surface treatments, maskings, parts flow, etc., are largely common to all three thermal spray processes used at the ALCs. The MT program should clearly identify cost drivers and impediments to productivity using methodical ICAM modeling techniques. These factors will be accounted for in designing and implementing the automated plasma spray cell. The cell will be implemented at San Antonio Air Logistics Center at Kelly AFB, Texas in late 1984. The contractor is Pratt & Whitney GPD, West Palm Beach, Florida.

PROGRAM

Objective:

Establish an automated cell for the application of selected plasma sprayed coatings during overhaul of gas turbine hardware at SA-ALC.

Benefits:

Increased productivity
Enhanced operator safety
Improved coating quality
Reduced cost
Improved reproductibility

PROGRAM APPROACH

- Systems approach
- Survey state-of-the-art technology
- Evaluate SA-ALC TSCP architecture
- Establish IDEF models - smart selection of APSC concepts/ components
- Improve scheduling
- Replace part inventory

PROGRAM APPROACH (PHASE I)

Define as-is SA-ALC spray coating operation

- Identify critical engine components
- Evaluate thermal spray coating operations
- Pre-spray surface preparation
- Post-spray coating treatment

Determine to-be models

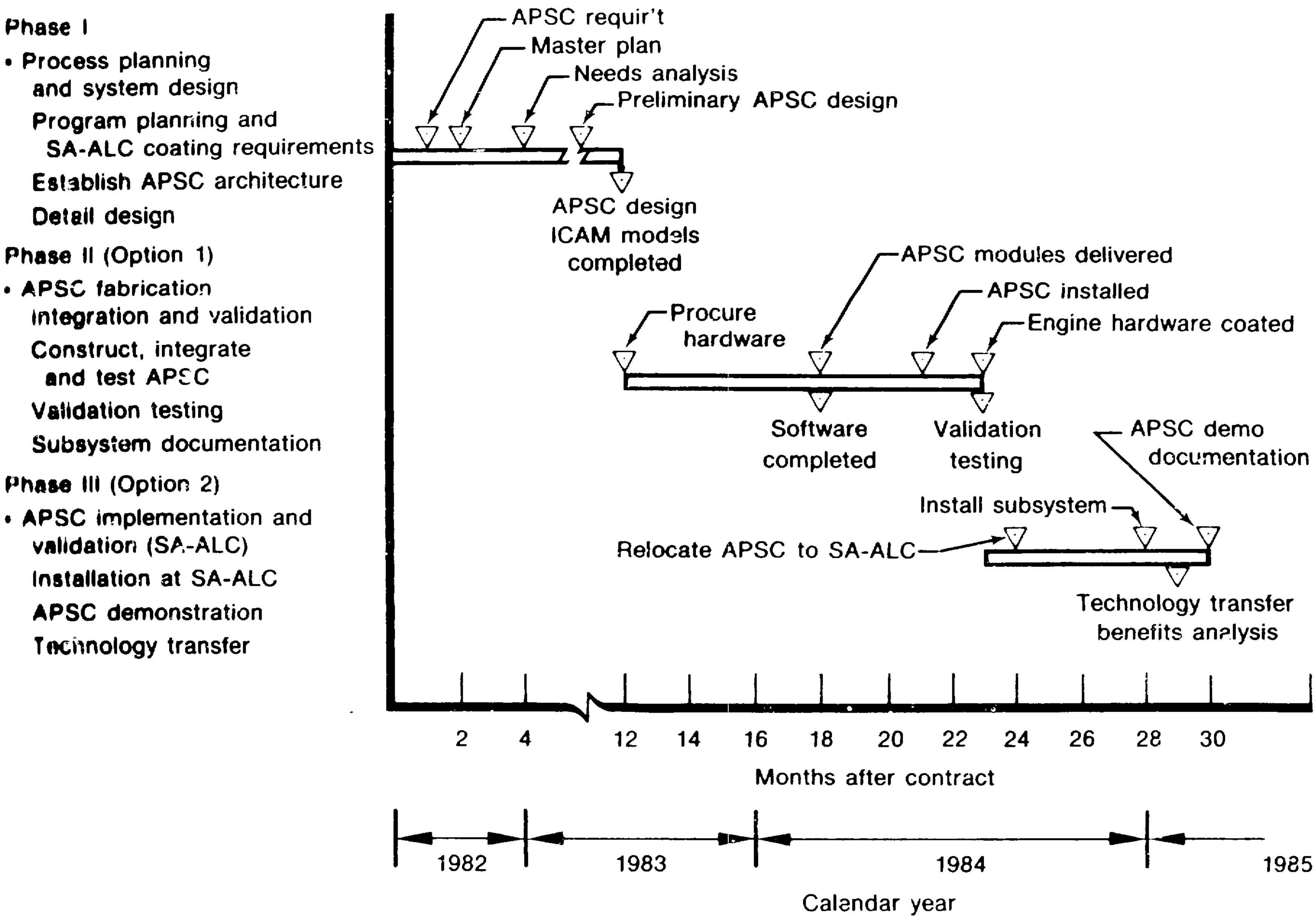
- Modular system approach
- Integrate computerized P/S process controls
- Roboticized plasma spray gun and grit blast guns
- Automate part transfer mechanisms

Establish preliminary APSC design
Obtain AFML and SA-ALC approval
Establish APSC design
Documentation

Establish SA-ALC P/S coating requirements

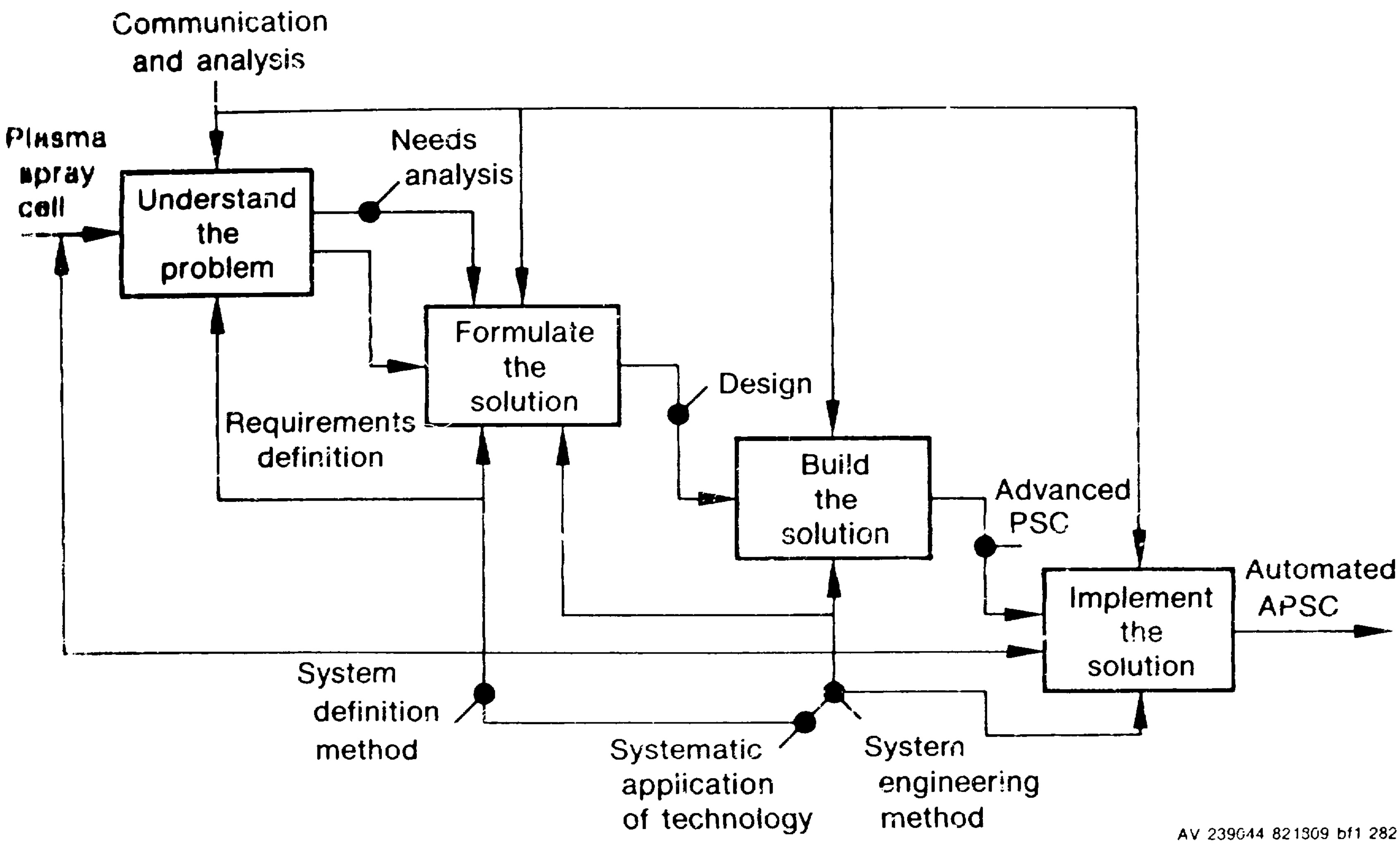
- Select engine components (3)
- Select sprayed coatings (3)
- Define APSC requirements
- Define AGBC requirements
- Define APTM requirements
- Determine base support needed

PROGRAM SCHEDULE - MANTECH FOR APSC



AV 235500 821809 bl1 285

PROGRAM METHODOLOGY



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PROBLEM

As-is manual and semi-automated spray coating operations at SA-ALC

- Low productivity
- Operator safety
- Scheduling
- High coating rework
- Operator technique dependence (reproducibility)
- Part damage
- Grit blast surface preparation (quality control)
- Grit blast and plasma spray equipment limitation

NEEDS ANALYSIS

Automation of TSCP and components

Operation	Assessed	To be Implemented
Part grit blasting	X	X
Part transfer/handling	X	X
Gun manipulation	X	X
Surface masking	X	No
Integration of quality control	X	X*

* Autom. thickness gage

TECHNOLOGY IMPACT

Benefits derived from Mantech program for automation of plasma spray process

- Increased productivity
- Enhanced operator safety
- Reduced cost
- Improved coating quality
- Improved reproducibility
- Process modernization

Benefits derived from automation of grit blast surface preparation

- Operator safety
- Improved productivity (3X)
- Repeatability (eliminate over/under blast)
- Increased engine component repairable life
- Reduced cost

ENGINE COMPONENT SELECTION CRITERIA

(Automation index)

Cost benefits

- F100 and TF39 engine coating application matrix

Part repair volume
Repair frequency
Replacement vs repair costs
Scheduling (inventory, logistics, equipment limitation, rework)

Improved quality
Spray coating complexity (manual vs automated)
Coating quality criticality

Enhanced operator safety
Processing time
Hazardous materials

SELECTED F100 PARTS AND COATINGS DESCRIPTION

Part description/Part No.	Grit blast	Bond coat (0.001 in.)	Top coat	Thickness (0.001 in.)	Comments
Divergent segment 4058690	60 SiC 80Al_2O_3	— NiAl (1-3)	WC-12Co MGO-ZRO_2 PWA 53-33	2-4 8-11	
Augmentor liner (FAB) 4047214	60 SiC 80Al_2O_3	NiAl (1-3)	MGO-ZRO_2 PWA 53-33	8-12	90SiC at P&WA/MD
Combustor chamber (BPH) 4057939	60 SiC 80Al_2O_3	NiAl (1-3)	MGO-ZRO_2 PWA 53-33	8-12	Inner and outer liners
10-13 Case (BHZ) 4056162	60 SiC 80Al_2O_3	—	NiCr6Al PWA 53-47 CR_3C_2-25 NiCr PWA 53-5	*(BTR) 5-8	
Exit stator (BPD) 4057183	60 SiC 80Al_2O_3	—	NiCr-6AL PWA 53-47 PWA 53-5	*(BTR) 5-8	Most complex part to repair

* BTR Build-up to tolerance requirement

AV258256 831103 3116B

SELECTED F100 PARTS AND COATINGS DESCRIPTION (Cont'd)

Part description/Part No.	Grit blast	Bond coat (0.001 in.)	Top coat	Thickness (0.001 in.)	Comments
12th vane and case (BHY) 405632	60 SiC $80Al_2O_3$	—	NiCr-6Al 53-47	*(BTR)	
RCVV actuation system (GBP) 4027670 (QBR) 4023053 4023083	60 SiC $80Al_2O_3$	—	Cu-38Ni PWA 53-69 WC-12Co PWA 53-1	10	

* BTR - Build-up to tolerance requirement

AV258256A 831403 3116B

SELECTED TF39 PARTS AND COATINGS DESCRIPTION

Part description/Part No.	Grit blast	Bond coat (0.001 in.)	Top coat	Thickness (0.001 in.)	Comments
FWD comp stator case (TF39)	60 SiC $80Al_2O_3$	NiAl (2-4)	Al	*(BTR)	Largest TF39 part (105/year)
OGY comp stator vane (TF39) 9685M86	60 SiC $80Al_2O_3$	NiAl (2-4)	Cu-Ni-In	*(BTR)	High volume (99 sets/year) at 108/set)

*BTR-build up to tolerance requirement

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GRIT BLAST AND PLASMA SPRAY COATING ESTIMATED OPERATION TIMES (MINS)

Operation	F100 augmentor liner			Divergent segment		
	Manual	Autom	Reduction %	Manual	Autom	Reduction %
Grit blast:						
• Load/unload	20	10	50	5	3	40
• Startup/shutdown	5	2	60	5	2	60
• Grit blast	95	32	66	14	5	65
• Clean/masking	36	36	0	15	15	0

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GRIT BLAST AND PLASMA SPRAY COATING ESTIMATED OPERATION TIMES (MINS) (Cont'd)

Operation	F100 augmentor liner Manual	F100 augmentor liner Autom	F100 augmentor liner Reduction %	Divergent segment Manual	Divergent segment Autom	Divergent segment Reduction %
Plasma spraying:						
• Load/unload	30	3	90	5	1	80
• Startup/shutdown	10	4	60	5	2	60
• Coating	300	210	30	16	11	31
• Thickness inspect	10	0	100	3	0	100
• Inspect/sign off	10	3	70	3	1	66
Total	516	300	42%	71	40	42%
Rework time (10% rate)	52	—		7	—	
	568		52%	78		53.5%

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ENGINE COMPONENTS RECOMMENDED FOR APSC

F100 engine

- Divergent segment (4058690)

  $MgO-ZrO_2$

  Wc-Co

- 10-13 comp case assembly (BHZ 4056162)

  NiCr-Al

  $Cr_3 C_2$ - NiCr

TF39 engine

- Fwd comp. stator case (9685M86)

  NiCr-Al

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APSC SYSTEM REQUIREMENTS

Flexible manufacturing cell

System flexibility

- Application versatility (parts and coatings)
- Process adaptability (batch vs random part processing)

Scheduling
- Operation management
- Part mix analysis

Automation
- Remote control
- Production scale operation
- Component durability

Flexible manufacturing cell

Integration
- Modular concept
- Supervisory control (software)
- TSCP compatibility
- Pre-and post-spray treatments

Operator skill
- Software
- Cell maintainability

CAD/CAM compatibility

APSC PROCESS FLOW

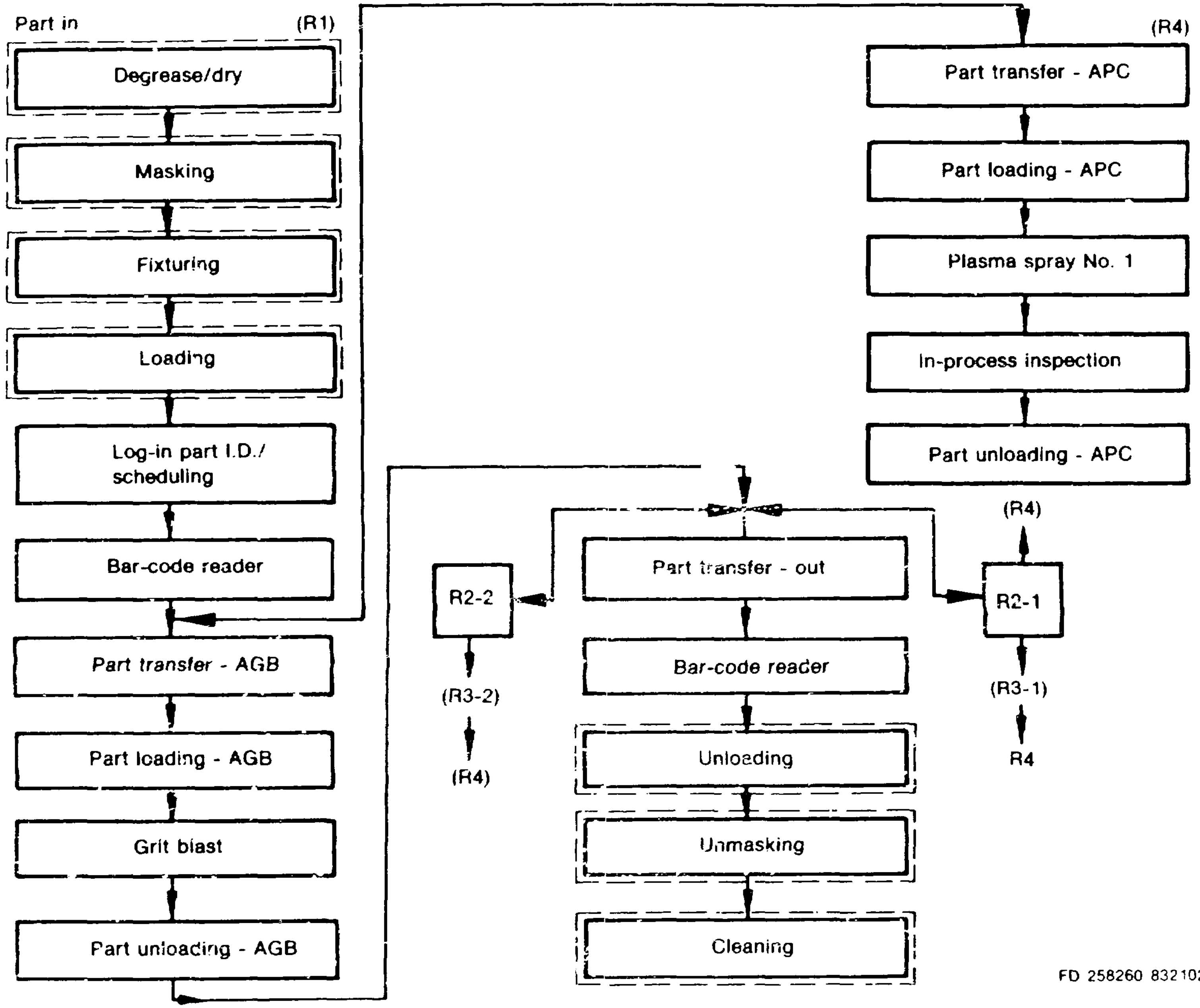
R1 - grit blast only
R2 - grit blast + plasma spray coating
1. No re-mask
2. Re-mask

R3 - grit blast + plasma spray coatings (multi-layers)
1. No re-mask
2. Re-mask after grit blast
3. Re-mask after 1st coating

R4 - plasma spray coating only

290

APSC PROCESS FLOW DIAGRAM



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AD-P004 005

AIR FORCE HONEYCOMB SHAPING AT SM-ALC
SACRAMENTO AIR LOGISTICS CENTER

BY: GERARD BETZ

The system described in this paper is being developed by Robotic Vision Systems, Inc. (RVSI) under a contract from Grumman Aerospace Corp. and is part of the Manufacturing Technology for Integration of Advance Repair Bonding Technique, Contract No. F33615-82-C-5054. Lockheed-Georgia is the prime contractor and the sponsor is the Air Force Wright Aeronautical Laboratory.

At present

The repair of bonded metal honeycomb aircraft structure is ~~is presently being~~ performed with manual techniques. These method~~s are very~~ labor intensive and result in repair qual~~ity very~~ much dependent on the skill and patience of the repairman. These manual techniques are not only costly in terms of repair labor and materials, but as a consequence of the long cycle time, ~~are~~ very costly in terms of aircraft availability ~~as well~~.

The system described in this paper will substantially decrease ~~the~~ repair cycle time and improve ~~the~~ quality of repair by providing an automated means to dimensionally define the repair area and accomplish accurate cutting and inspection of honeycomb structures.

The optical measurement system has the ability to accurately digitize the entire surface contours of the area to be repaired in significantly less time than provided by contacting systems. Further, since an optical measurement technique will be used ~~employed~~, there will be no danger of core damage which can be caused by a contact measurement probes device.

The system consists of presently available sub-systems integrated together to provide a flexible computer controlled repair or manufacturing cell. The cycle time of the portions of the repair cycle which involve the measurement of the core cavity, the design of the honeycomb repair plug, cutting the plug, measuring the plug to verify if it has been cut to the correct dimensions and the final inspection of the repair will be reduced by an order of magnitude. Further, the quality of the repair will be substantially enhanced as a consequence of the elimination of the "cut and try" manual procedures presently required.

Optical Measurement System Description

The Optical Measurement System, shown in Figure 1, will be provided by RVSI. It scans the part to be repaired and processes the data such that it can be stored on a disc or magnetic tape that can be read by the CAD/CAM system. The data collection and digitizing is performed by the optical scanning equipment. The equipment shown in Figure 2 consists of an RVSI 3-D electro-optical sensor (Robo Sensor) mounted to the tool plate of a 6 axes gantry style robot. The robot has a horizontal motion range of 8 ft. by 10 ft. This will accommodate the largest honeycomb sections described by the Air Force and will have the ability to map surfaces approximately 7 ft. by 9 ft. without requiring movement of the honeycomb assembly.

Operator Sequence

Using the OMS as part of an automated honeycomb repair center, a repair will be accomplished following the steps outlined below.

a. Using NDE techniques, the damages area is found, and the cover and damaged core is removed. The cavity is cleaned and prepared.

b. The part is placed within the operating volume of the measurement system, and the operator establishes the scan pattern. This is accomplished by leading the robot to a sufficient number of points to define the scan limits. For simple surfaces this requires two (2) points on diagonal corners of the scan area. More complex parts may require more points but usually no more tnan six. Next the operator enters the scan parameters (i.e., sample rate).

c. Based on the programmed scan pattern, the measurement system scans the defined surface and makes surface measurements as requested. The system filters and thins the data prior to loading onto a magnetic tape which will be processed by the CAD/CAM system. To fully define the surface, the system will scan the surface twice with the second scan orthogonal to the first.

d. The CAD operator will use the data, which is formatted as sequential cuts through the part to generate a wire frame model of the cavity and surrounding surface. (see Figures 3, 4 and 5)

e. The operator then uses the surface model to generate an APT tape to drive the five-axis profiler.

f. The core is fabricated on the five-axis profiler using the APT file generated on the CAD system.

g. The replacement core is fit-tested, and the part bonded.

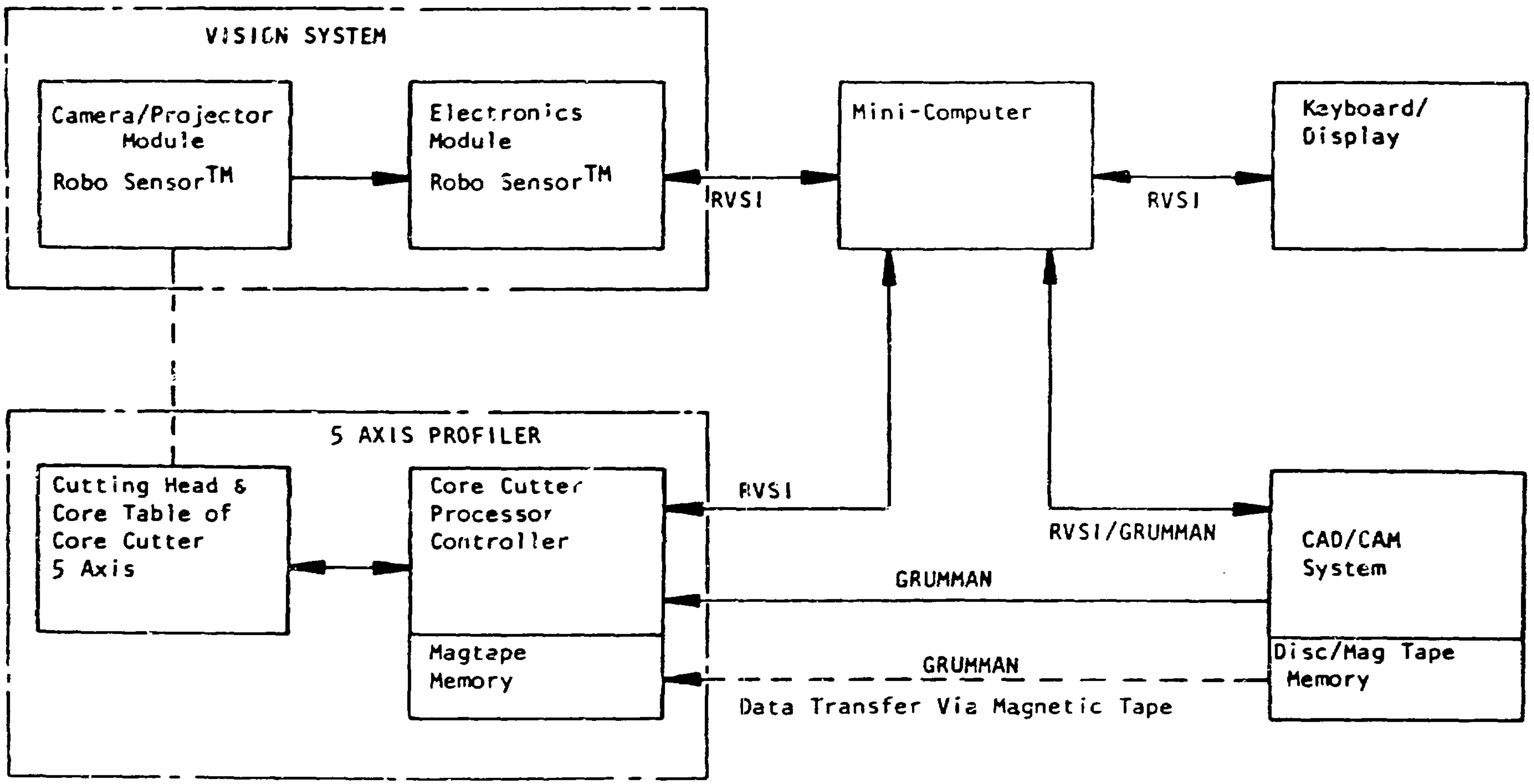
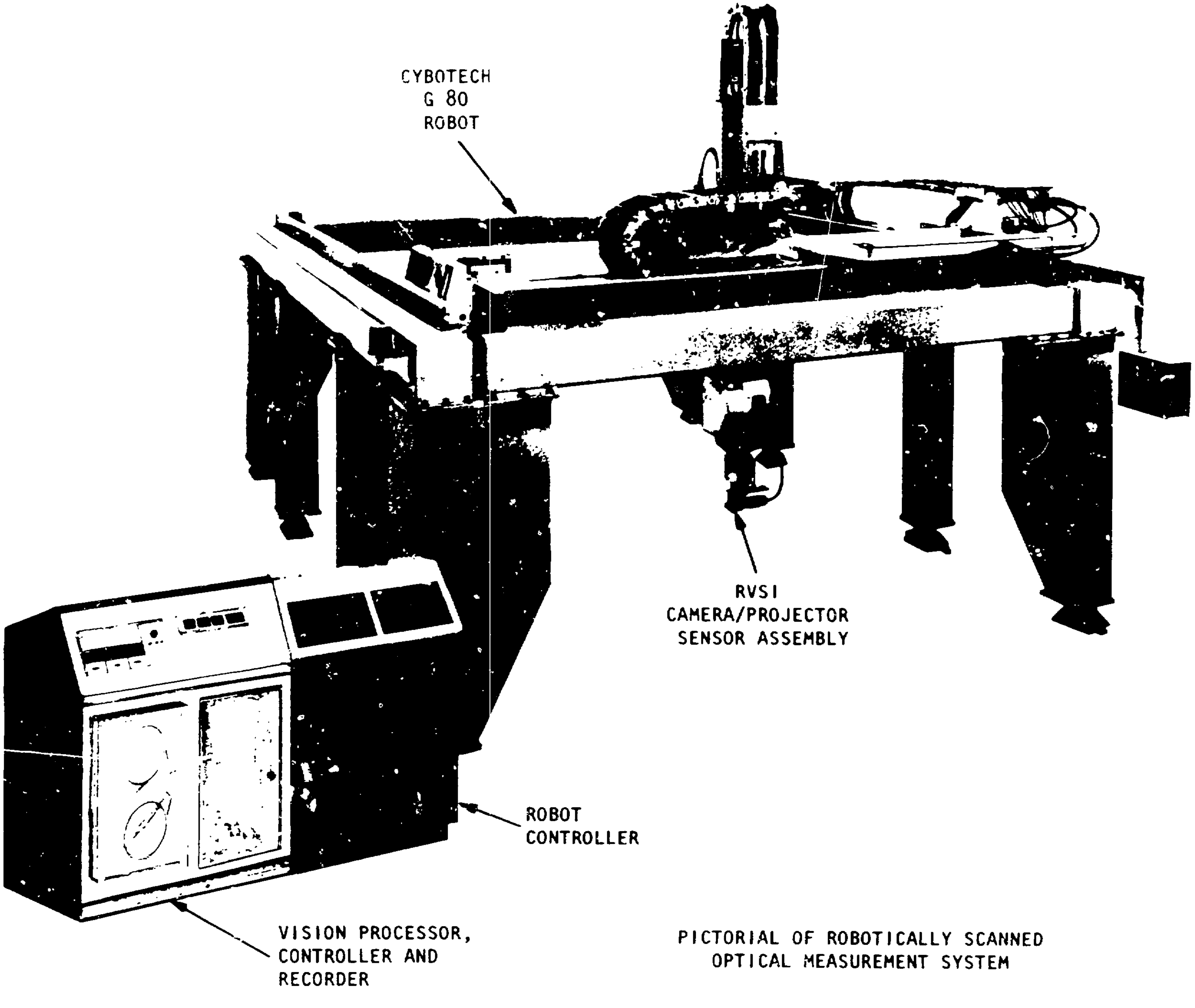
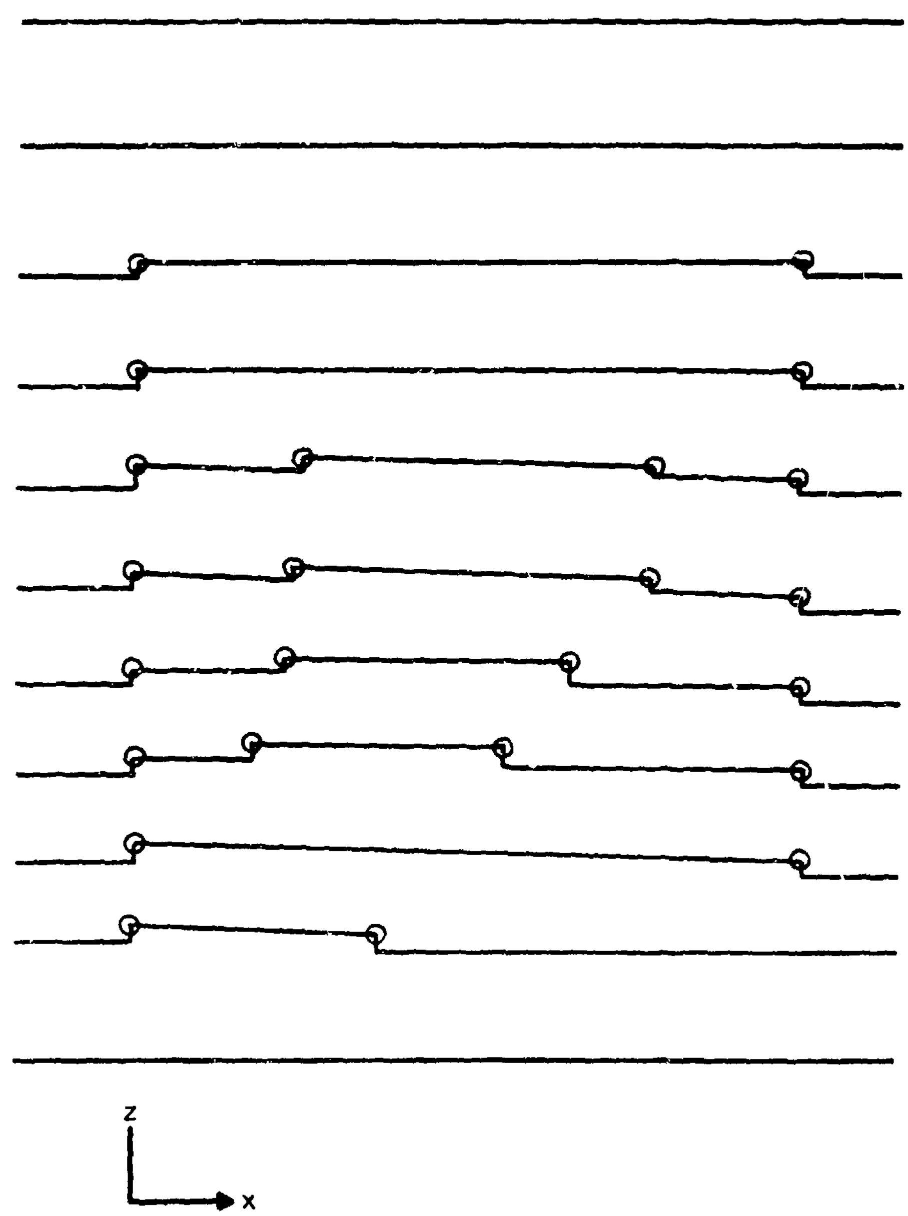


FIGURE 1

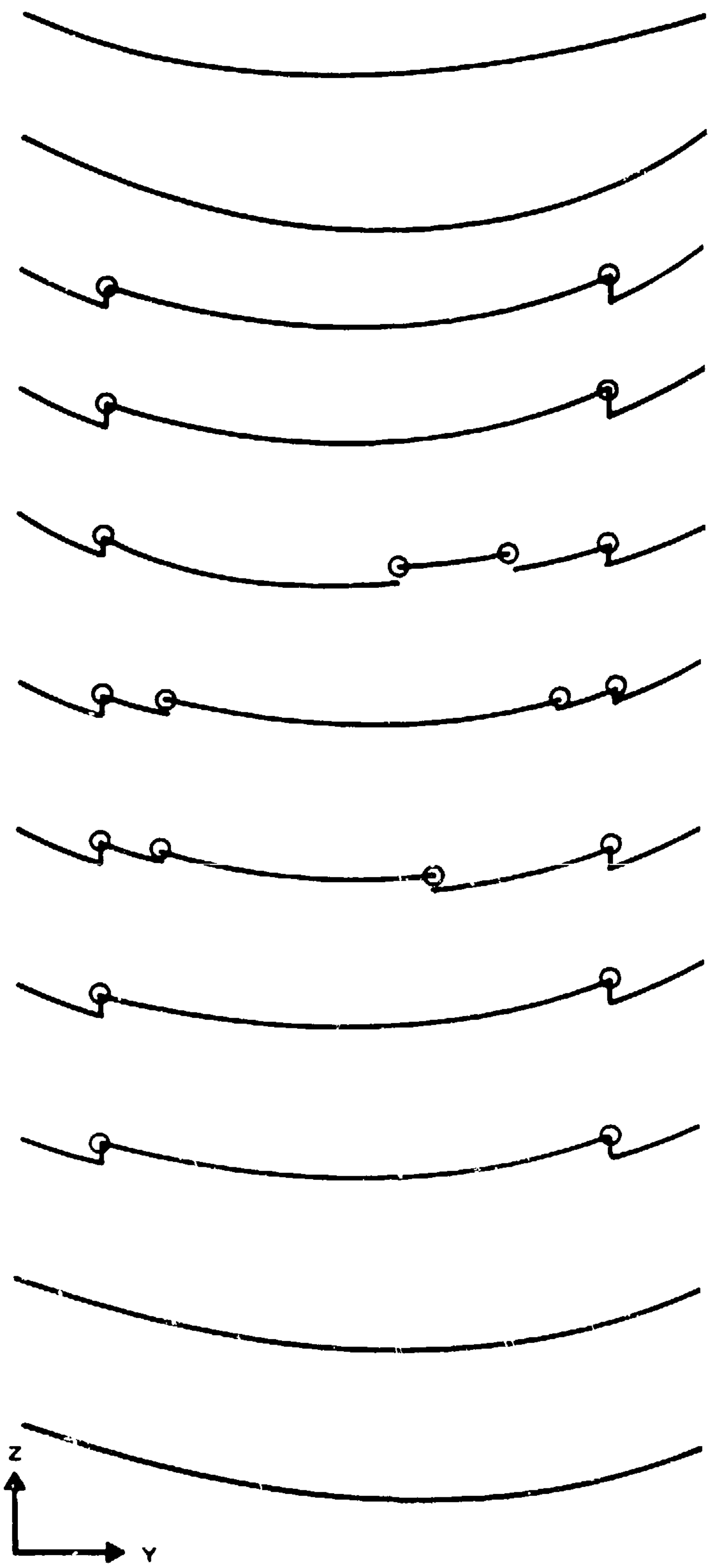
BLOCK DIAGRAM OF AUTOMATED HONEYCOMB REPAIR AND INSPECTION SYSTEM



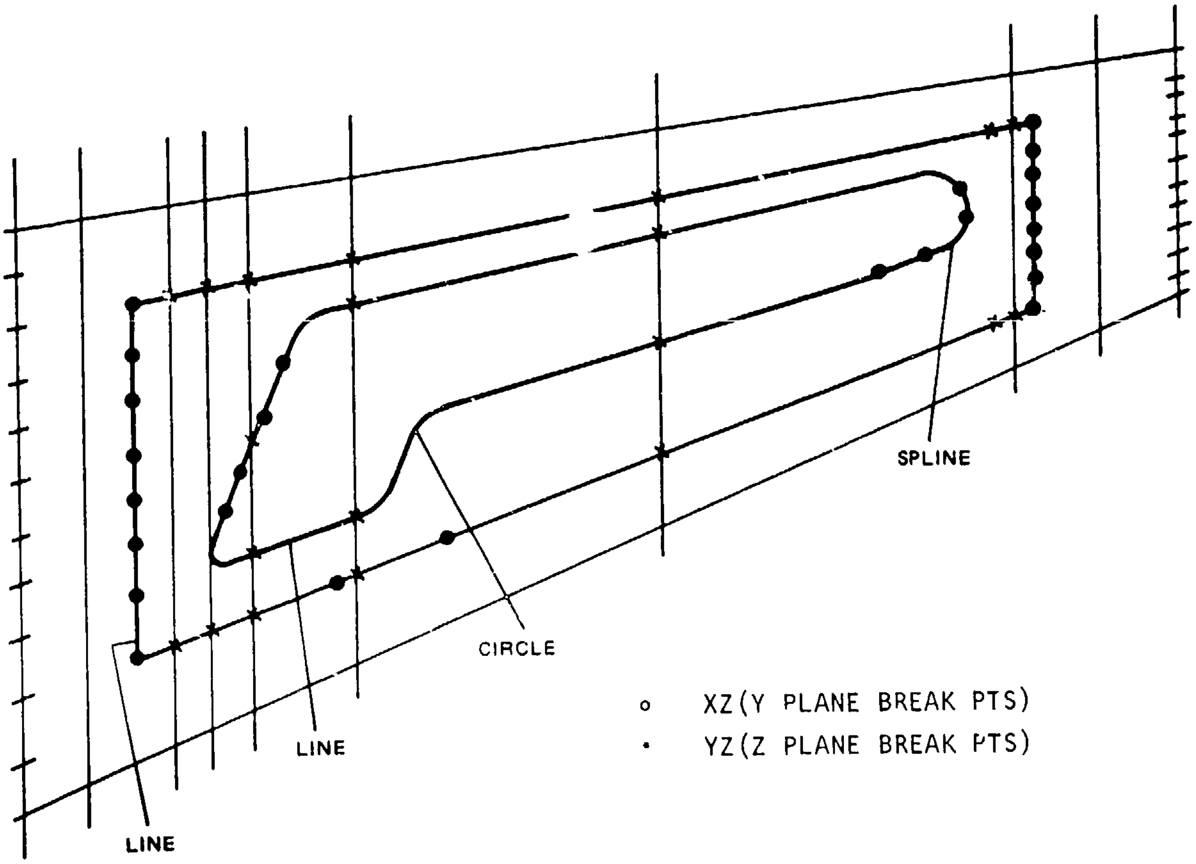
PICTORIAL OF ROBOTICALLY SCANNED
OPTICAL MEASUREMENT SYSTEM



EXAMPLE OF DATA FROM CONSTANT
Y PLANE DATA SLICES



EXAMPLE OF DATA FROM CONSTANT
X PLANE DATA SLICES



CAD REPRESENTATION
OF
COMBINED DATA

Results of Feasibility Demonstration

In order to verify the ability of an optical 3-D sensor to measure specular surfaces such as honeycomb and aircraft skins, a section of metal honeycomb and a test honeycomb assembly were scanned using RVSI's "Industrial Sensor". The "Industrial Sensor" is a 4 axes precision 3-D electro-optical measurement system which RVSI had developed and is using in a variety of government and industrial programs.

A photograph of the assembly being scanned is shown in Figure 6. The piece was mounted in the "Industrial Sensor" and scanned along with the x axis. After each x scan, the unit was indexed in z (height) and another x scan taken. This was repeated until the entire surface around the cavity was mapped. Each x scan maps 0.5 inches in the z direction; therefore, the entire surface mapping required only twelve scans. A stacked contour representation of the data is shown in Figure 7. A stacked contour display is an isometric representation of a 3-D data scan.

A more accurate view of the 3-D data is obtained by looking at a single cross section of a plane passed through the data. This data shown in Figure 8, shows two steps in the cover surface. These steps are indicated by the two circles. The circle on the left encompasses a 0.020 inch step and the circle on the right encompasses a 0.004 inch step. Although the 0.004 inch step is difficult to see at the scale factor used for the plot, curve fits passed through the data verified the step location and size.

The data presented above contains a data simple every 0.010 inch. Data of this density would overload a CAD system, therefore a thinning algorithm will be used to reduce the data density. The results of the automatic data thinning is shown in Figure 9. In Figure 9a a 0.1 inch step in a flat plate was detected and only 4 points, shown as X's were reported. These 4 points fully describe the surface. In Figure 9b, a section of a cylinder of radius 2.5 inches was scanned and the data reduced. The 9 X's shown super-imposed on the raw 3-D data fully describe the surface.

A sample piece of honeycomb with a milled 0.020 inch step was used to test the ability of the optical 3-D sensor to detect a step in honeycomb. The sample had no protection coating. The sample is shown in Figure 10. A detailed frontal view is shown in Figure 11a and a side orthogonal view is shown in Figure 11b.

The step is clearly visible in Figure 11b. An analysis of the data points shown the average height, the y value, of the data outside of the milled area is 0.438 inches and the average height of the data in the milled area is 0.416 inches which indicates that the step is 0.022 inches deep.

HONEYCOMB ASSEMBLY SHOWN ON OPTICAL SENSOR TRANSLATION UNIT

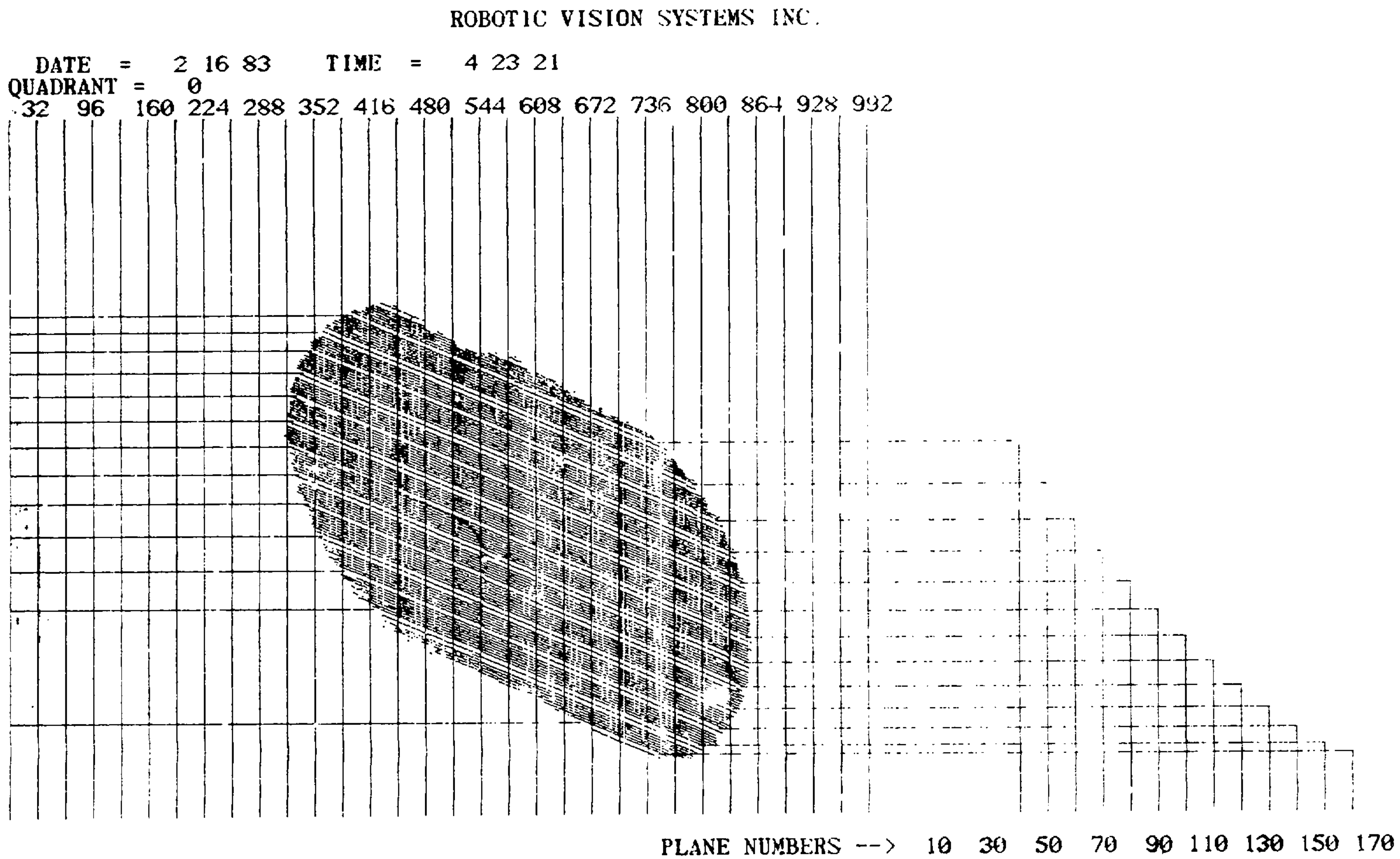


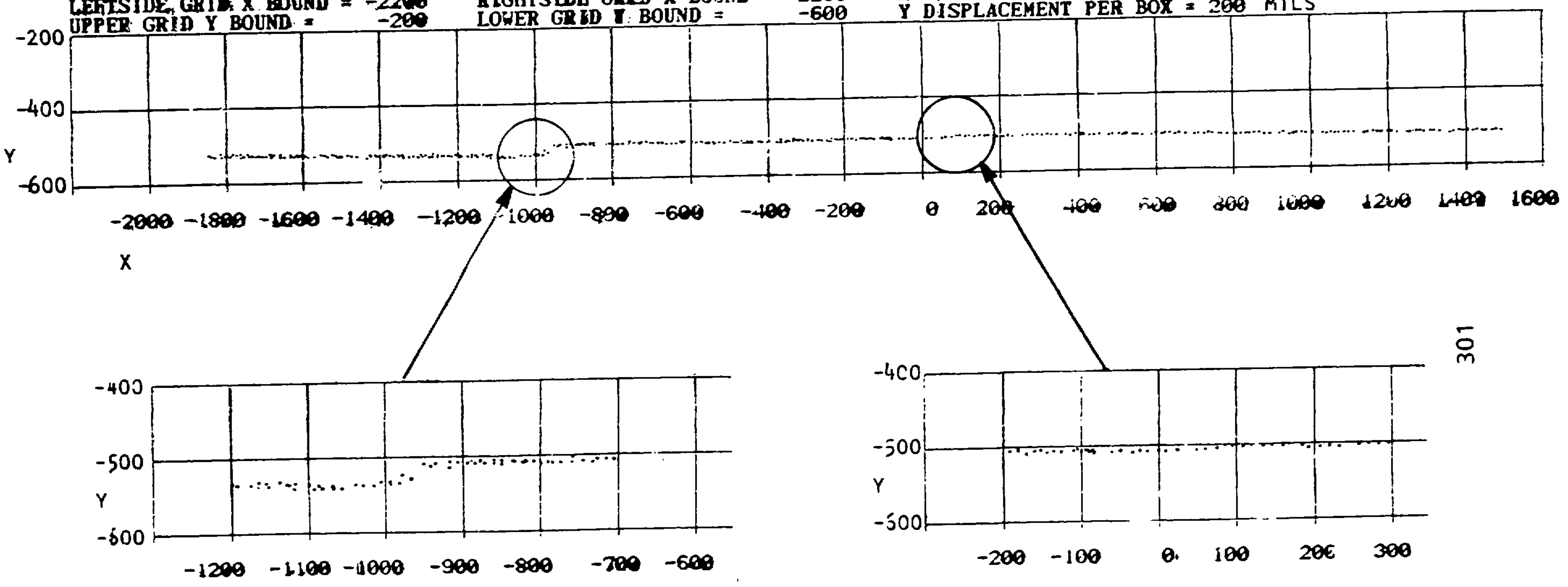
FIGURE 2-10
STACKED CONTOUR OF HONEYCOMB ASSEMBLY
(BOTTOM SKIN ONLY)

ROBOTIC VISION SYSTEMS INC.

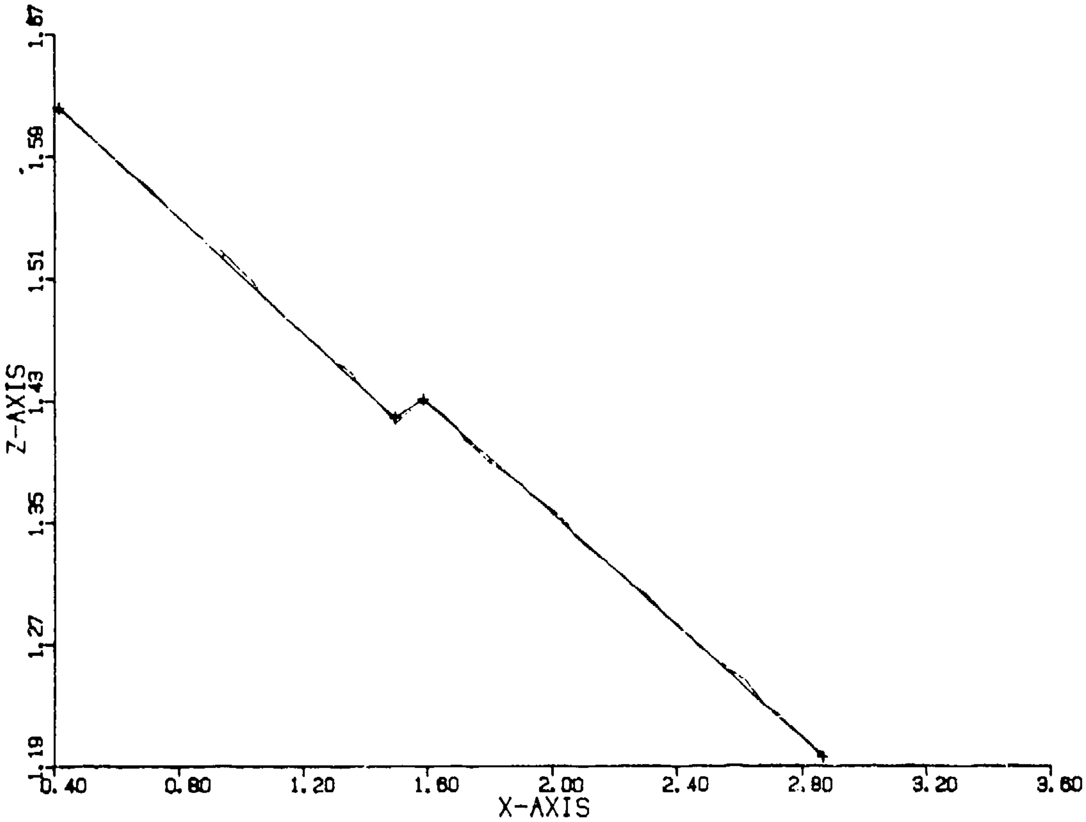
DATE = 2 24 83 TIME = 10 41 59
SCALE FACTOR = 2
LEFTSIDE GRID X BOUND = -2200
UPPER GRID Y BOUND = -200

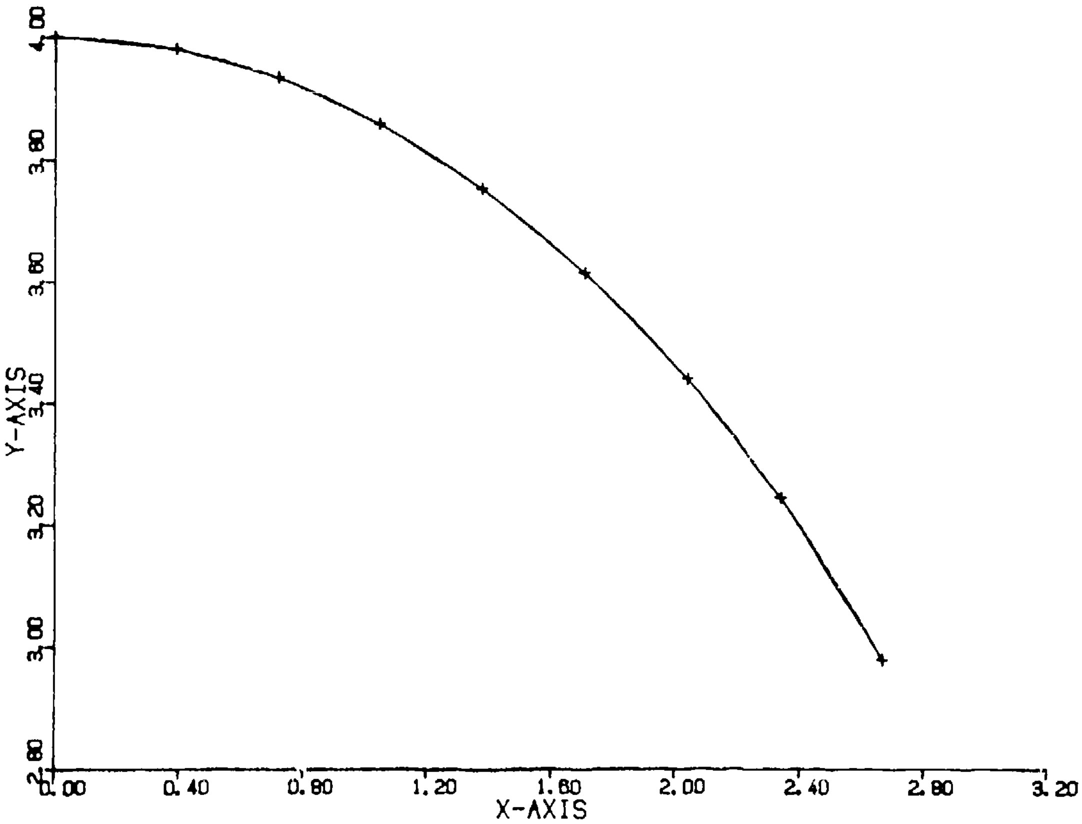
NUMBER OF PAIRS PLOTTED = 2970
RIGHTSIDE GRID X BOUND = 2200
LOWER GRID Y BOUND = -600

X DISPLACEMENT PER BOX = 200 MILS
Y DISPLACEMENT PER BOX = 200 MILS

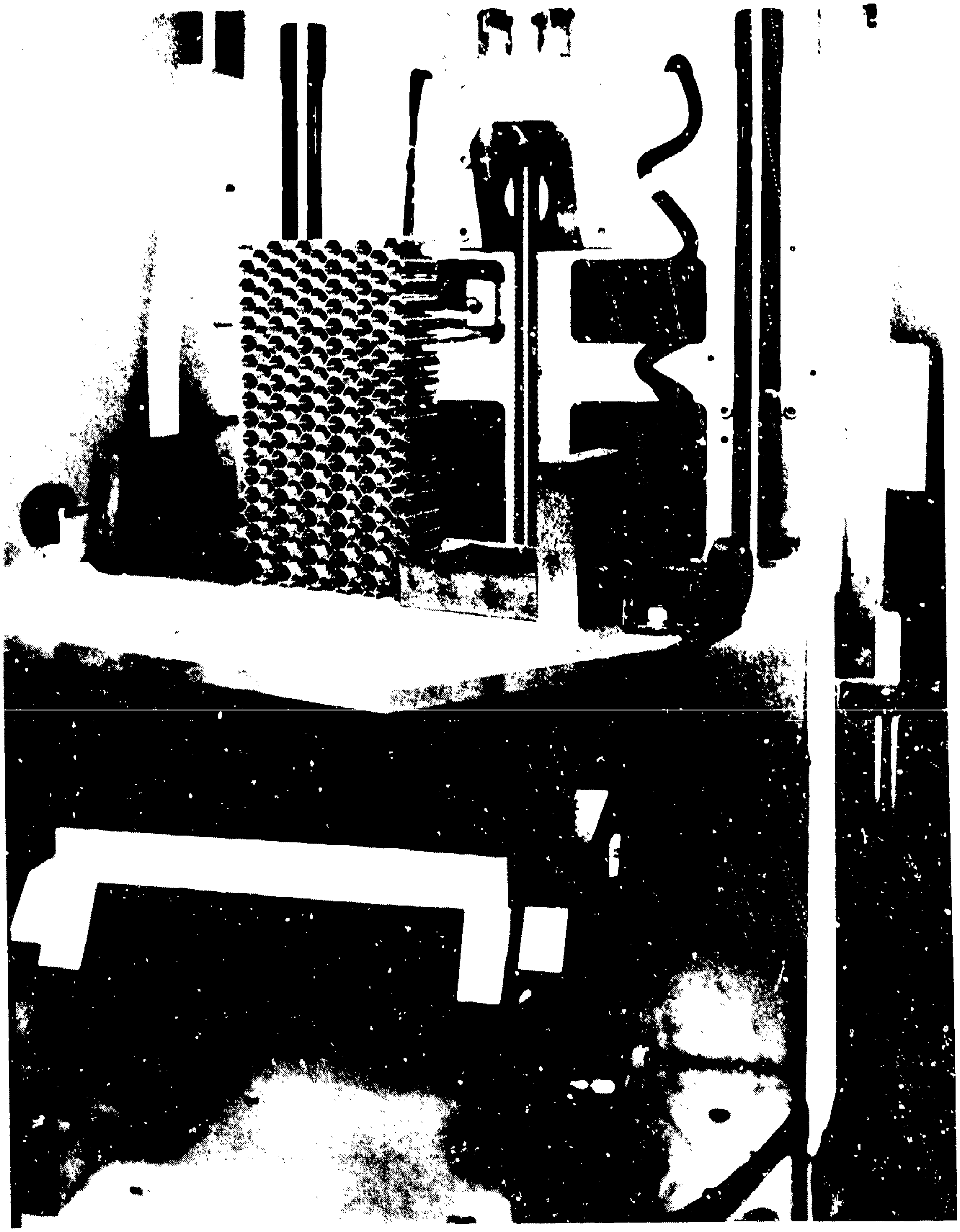


SLICE THROUGH FLOOR SECTION





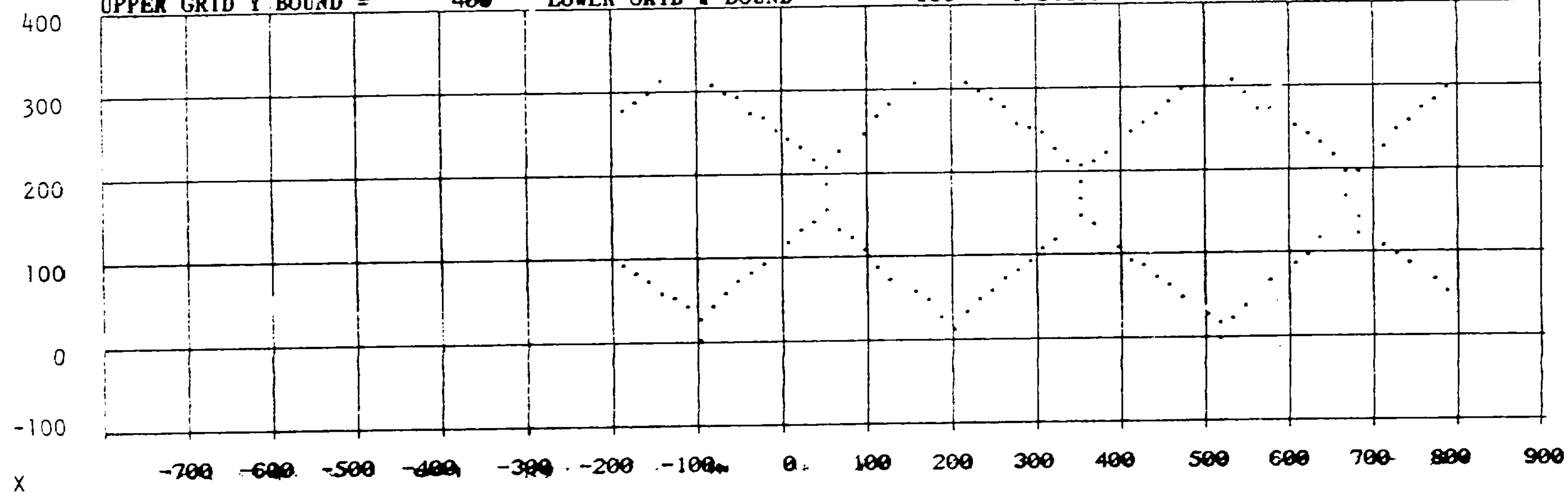
AUTO DATA THINNING RESULTS



LARGE HONEYCOMB CORE SHOWN ON OPTICAL SENSOR TRANSLATION UNIT

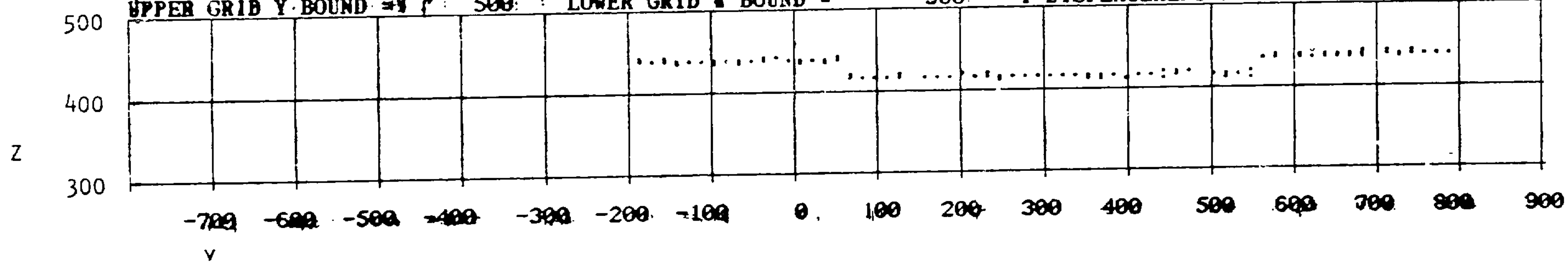
ROBOTIC VISION SYSTEMS INC.

DATE = 2 25 83 TIME = 10 30 0
SCALE FACTOR = 1
LEFTSIDE GRID X BOUND = -800
UPPER GRID Y BOUND = 400
NUMBER OF PAIRS PLOTTED = 1044
RIGHTSIDE GRID X BOUND = 1400
LOWER GRID Y BOUND = -100
X DISPLACEMENT PER BOX = 100 MILS
Y DISPLACEMENT PER BOX = 100 MILS



EXPANDED FRONTAL VIEW
OF HONEYCOMB

DATE = 2 25 83 TIME = 10 32 23
SCALE FACTOR = 1
LEFTSIDE GRID X BOUND = -800
UPPER GRID Y BOUND = 500
NUMBER OF PAIRS PLOTTED = 1044
RIGHTSIDE GRID X BOUND = 1400
LOWER GRID Y BOUND = 300
X DISPLACEMENT PER BOX = 100 MILS
Y DISPLACEMENT PER BOX = 100 MILS



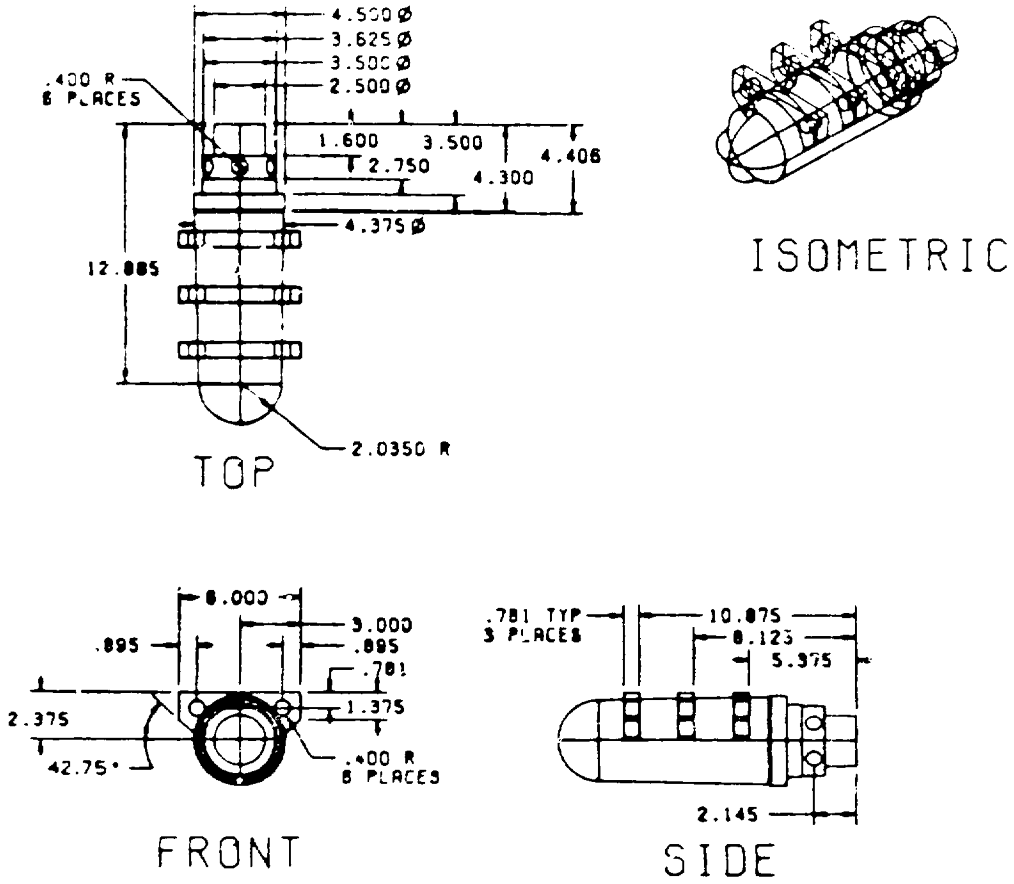
EXPANDED ROTATED VIEW
OF HONEYCOMB

Summary

The Optical Measurement System will be able to rapidly acquire data from honeycomb and other surfaces. This data will be automatically processed and converted into an IGES (Initial Graphics Exchange Specification ANSI Y14.26) format. The ability to acquire, process and transfer 3-D data to a CAD system has already been demonstrated under a Navy contract. Under this contract a test sample was scanned and 3-D data file in IGES format was generated. The IGES file was processed in a Computer Vision CAD system by the Navy at its China Lake facility. The results are shown in Figure 12.

Vision guided robots will have broad application in the future. Such tasks which can be performed by robots assisted by vision include:

- o DRILLING
- o ROUTING
- o DE-RIVETING
- o WELDING
- o DEBURRING
- o OBSOLETE PARTS MEASUREMENT AND FABRICATION.



GENERAL NOTES

1. THIS DRAWING REPRESENTS A PART CREATED FROM THE COMPOSITE IGES DATA BASE SHOWN ON SHEET 3.

2. ENGINEERING ASSUMPTIONS HAVE BEEN MADE TO RECTIFY DISPARITIES IN THE TWO DATA BASES.

3. DIMENSIONS SHOWN ON THIS PART HAVE BEEN DERIVED FROM THE DIMENSIONAL VALUES OF THE ORIGINAL IGES DATABASES.

4. DIMENSIONAL VALUES REPRESENT AVERAGES OF ORIGINAL DIMENSIONS, ROUNDED TO COMMON FRACTIONAL VALUES.

FINAL DRAWING DEVELOPED FROM
IGES DATABASES 1 AND 2

COMPUTER AIDED ENGINEERING OFFICE
NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA

ROBOTICS - IGES
PART DATA INTERPRETATION

C CAESO-001

1/4 6 OF 6

CAESO-001 6

AIR FORCE, ROBOTIC PAINTING

-OGDEN AIR LOGISTICS CENTER, RESOURCES MANAGEMENT DIVISION-
OC-ALC/MAW

BY: COLONEL RONALD V. GRABLER

Ogden Air Logistics Center will discuss, in a few minute review, the proposed future applications of robotics in an aerospace industrial facility. Several topics of discussion will include painting, flame spray, deriv ing, welding, shop peening, drilling, measuring, and electronic card repair.

Good morning, I m Colonel Ronald V. Grabler, Chief, Resources Management Division, Directorate of Maintenance, Ogden Air Logistics Center which is located 30 miles North of Salt Lake City, Utah. I'll present our experiences with the Devilbiss/Trallfa TR-3500 robot that ~~we~~ use for stripping and painting U.S. Air Force sidewinder missiles at the Ogden depot. This is our first installation, but certainly not the last.

This briefing was prepared primarily for our counterparts who are considering their first application in hopes that they can learn from our experiences. I believe we lived through every point that industry presented yesterday morning.

Now, in our view, what are the keys to successful installation? One of the most important factors in a first installation, is that of design. Simplicity in design of the holding fixtures, indexing system and the handling equipment.

The operation we selected was stripping and painting of an AIM-9 sidewinder missile. We wanted to do both stripping and painting operations from a single location (Slide #1).

The selection of the Devilbiss robot was made because it fulfilled our requirements, plus it is easy to program, is flexible and has an excellent service record (Slide #2).

The robot has two paint guns on the manipulator: One for spraying stripper and the other for applying the polyurethane paint (Slide #3).

Training on the robot means that the operator must program it to accomplish each task. The operator/programmer takes the programming controls and guides it through each gesture while the computer memory records each step.

Our particular robot computer has the capacity for 64 programs - thus providing adequate flexibility for future applications.

During the stripping operations, the robot sprays chemical stripper on the missile as it passes by on a chain-on-edge conveyor. When the missile enters the booth, the holding fixture trips a switch that stops the conveyor and tells the robot to begin the stripping operation. The robot sprays a portion of the missile, then waits as the conveyor advances it and partially turns it as it is advancing to the next stop. The process is repeated until full application of the stripper is accomplished. Once covered with stripper, the missile advances on the conveyor to a rinse booth where the loosened paint is brushed off and the missile is rinsed and air dried. The missile is then detailed by masking it and plugging several critical openings.

When the detail work is completed and is ready for painting, the missile and holding fixture is placed on an adjacent chain-on-edge conveyor. The missile enters the paint booth, trips a switch and goes through the same type of indexing as in the stripping booth.

Now that we have gained experience with a simple app ication, we are branching out to other work loads so as to employ the robot full time. There are approximately 40,000 item per year that we can paint through robotics. To accomplish that, we designed a universal fixture, (SLIDE #4) that was easily adaptable to many types, shapes and sizes of small instruments. This is the fixture with several adapter arms and different shaped cases requiring finishing. By going to a universal fixture, we have reduced complexity, storage requirements, and costs. Some items we can paint are, the B-52 astrotracker - before (SLIDE #5) and after // (SLIDE #6) and an amplifier indicator case // (SLIDE #7).

Now, let me transition to another item. One of our key considerations was to remove man from a toxic environment created by polyurethane paint. A painter wearing a suit is not nearly as efficient as a robot that is impervious to the conditions within which it works. In fact, we physically removed the painter from the paint booth and located him in an enclosed control room from which he monitors and controls the operation. The union is also pleased with that move

As a wrap up on the points we feel are important for your first installation, consider a relatively simple operation that will let you learn and grow with the system. Also, design a system that can take added work load at a later date. Design multiple use fixtures when possible and feasible. Safety can help sell your plan. Look at your dangerous, hazardous areas for a payoff. Finally, look critically at the track record of the robotic companies

bidding on your installation. Select a robot with a good record. Check with their customers on service, training, and support. You cannot afford to install automation and have problems.

I'd like to touch briefly on several minor problems we've had. One of them was that the stripper was too thick, and plugged the spray gun. It was easily solved by proper thinning and putting the stripper in a pressure pot. Another problem that was encountered was when the paint booth exhaust system was operating, it robbed the stripping booth of make up air. We found that by installing controls on each of the paint and stripping booths, and connecting into the control panel, we now operate each exhaust blower independently; thereby balancing our air requirements. The only problem that we have had with the robot was created by a dirty floppy disc. It was dropped on the floor and then put into the control panel. The robot was going through the paint program when it stopped. It took about 20 minutes to identify and solve the problem. Better care in the handling and storage of the disc was taken. Also, we now make copies of our master program and store the master in a clean safe place.

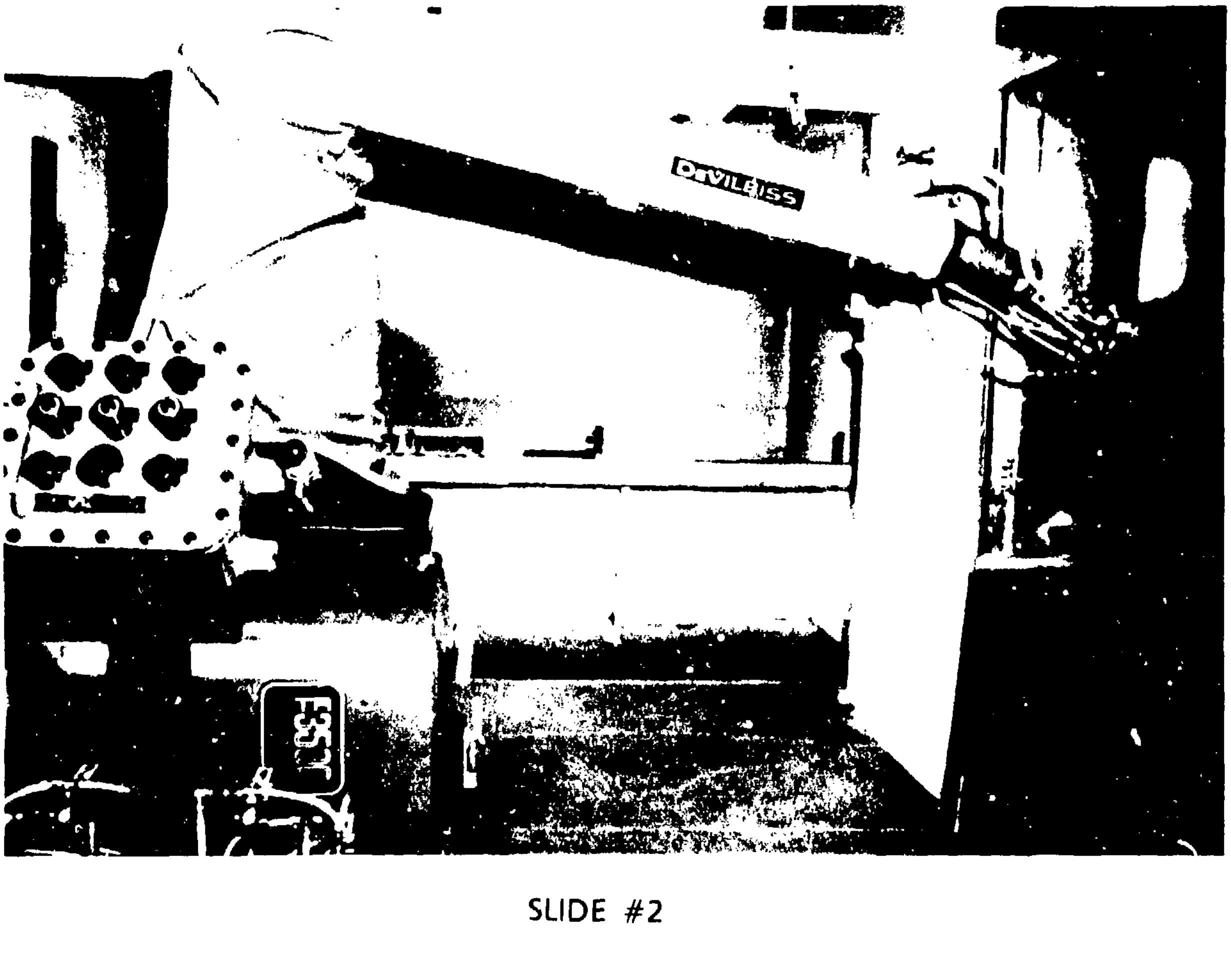
In summary, we have had very few problems with our installation----, but as you can see, most of the problems were not serious, but should have been anticipated.

Are there payoffs to us? Of course there are. Let me touch upon a few. Reduced cost of material is one. When we experienced the problem with the thick stripper, we found out that we were stripping by hand, we used one quart of stripper per missile, now that it has been thinned and put in a pressure pot, we are using only one-fourth of that amount, or a 75% saving. Reduced cost of energy occurred from our installation of separate controls to the paint and stripping booths for our make up air problem. This reduced our energy by 50%. We also reduced rejects. Once the robot is programmed, it repeats each action precisely the same way each time. It will continue to repeat the identical process for the every missile, applying a perfect paint job each time. We have not quantified the dollar savings in reduced rejects, but we know they exist. We've already touched upon removing the painter from a hazardous area. The other aspect is, that by installing the robot, we've expanded the painters responsibilities and have enriched his job. A real satisfaction for him.

In conclusion, there is a definite need and role for robotics in a repair facility. Proper application can enhance productivity. If you choose to install a robot, do several things as such as: Look for a turnkey operation; capitalize on the knowledge of the manufacturer - they are the pro's. Let them be responsible for the package. Talk with other users about problems they may be experiencing; look at the service record of the company; and finally, ensure you scrupuously comply with all environmental and fire safety requirements.

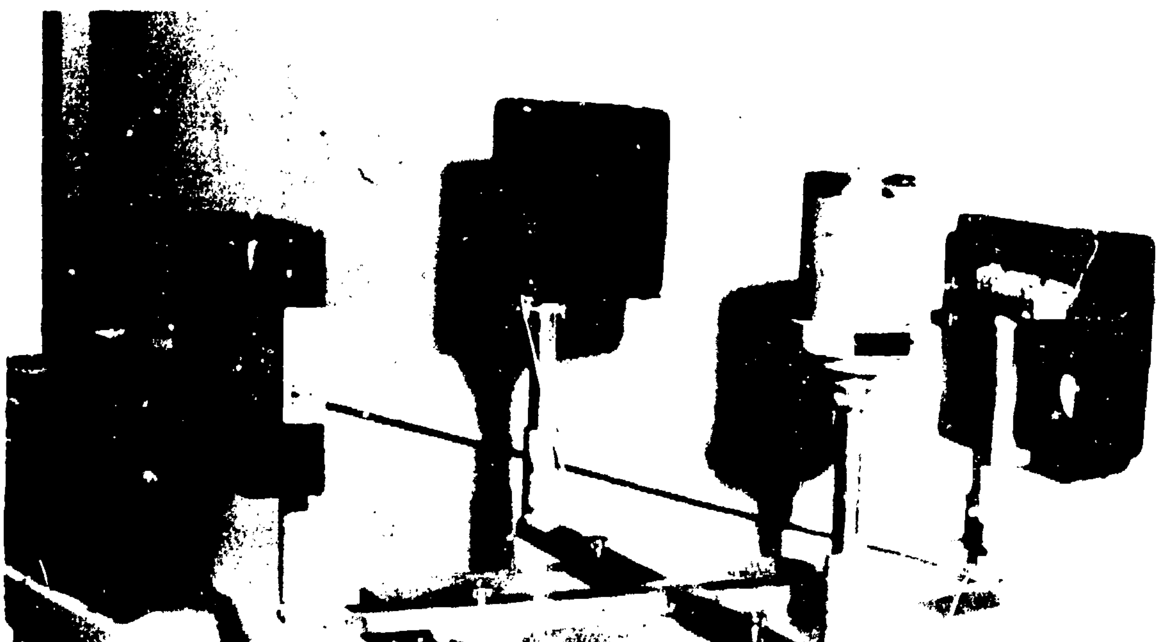
We at Ogden are enthusiastic about our installation and are planning to install two more robots for a new work load in the next several months. We'll talk more about that during our briefing on future applications at Ogden.

SLIDE #1



SLIDE #2

SLIDE #3



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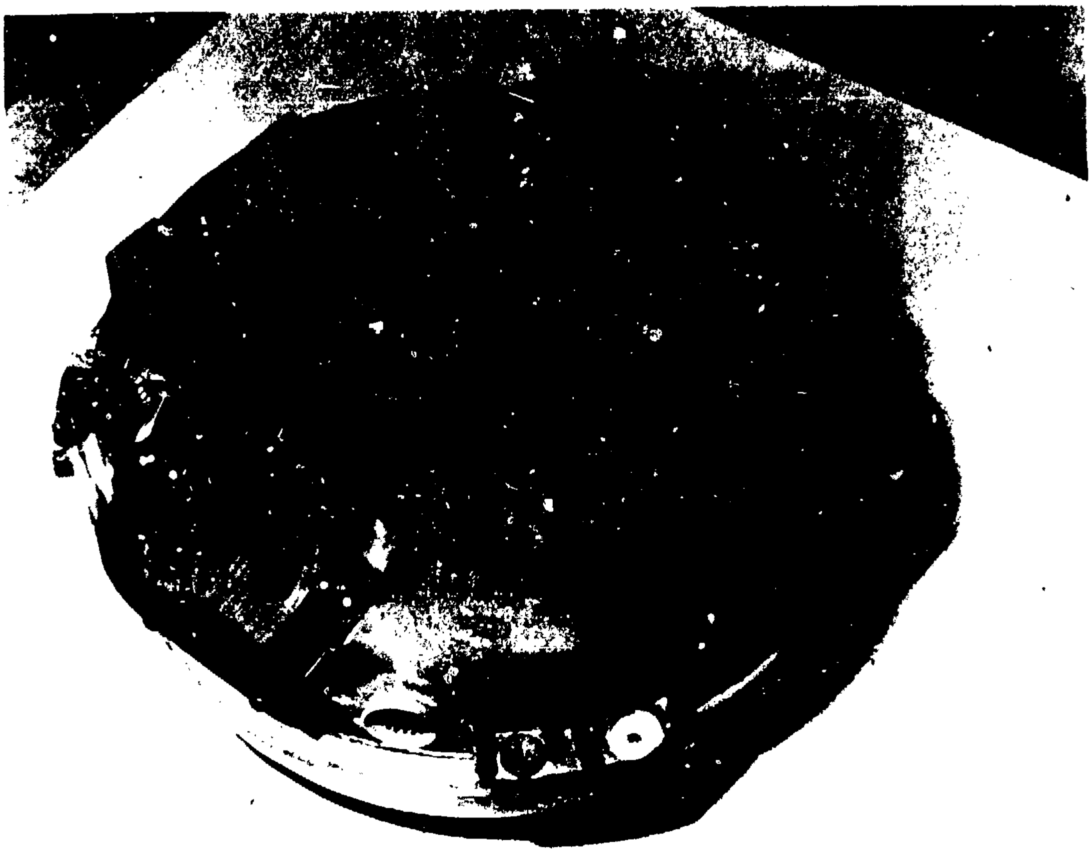

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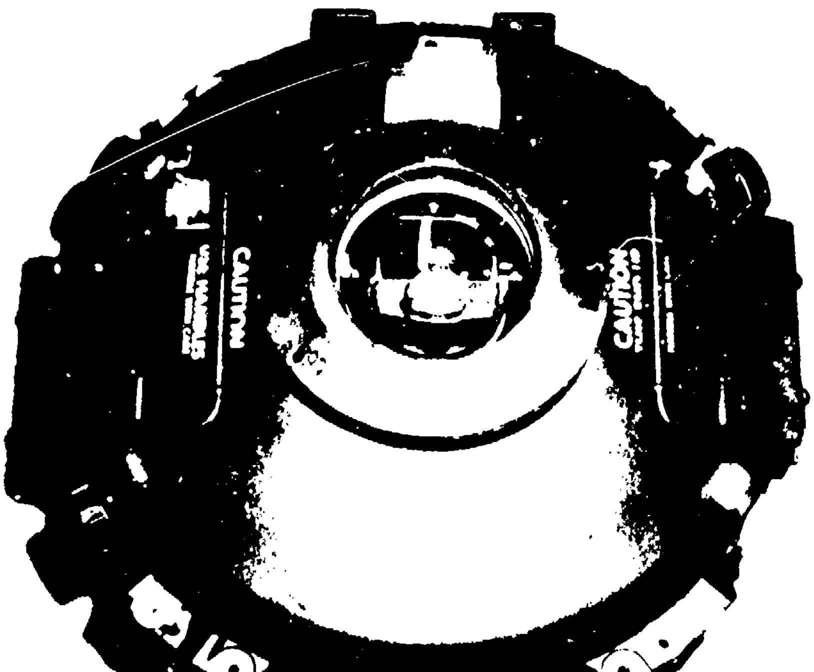


SLIDE #6

SLIDE #7

NAVAL AIR REWORK FACILITY, ALAMEDA
BY: BARRY SAVNIK

ON AIRCRAFT REPAIR OF P-3 ENGINE SHROUDING

PROBLEM

FOR ROUTINE REPAIRS OF P-3 ENGINE SHROUDS THE ENTIRE ENGINE MUST BE REMOVED FROM THE AIRCRAFT TO FACILITATE REMOVAL OF THE SHROUDS.

OBJECTIVE

PROVIDE PROTOTYPE EQUIPMENT AND PROCEDURES FOR 'ON AIRCRAFT' REPAIR OF P-3 ENGINE SHROUDS.

APPROACH

. DEVELOP A SUITABLE ROBOTIC DEVICE

. CLEAN THE INNER SHROUD SURFACE

. LOCATE THE DEFECTS ON THE SHROUD SURFACE

. PATCH THE DEFECTS

. APPLY CORROSION - RESISTANT COATING

MISC

. DATE OF AWARD - 19 SEPTEMBER 1982

. CONTRACT COST - $1,365,000

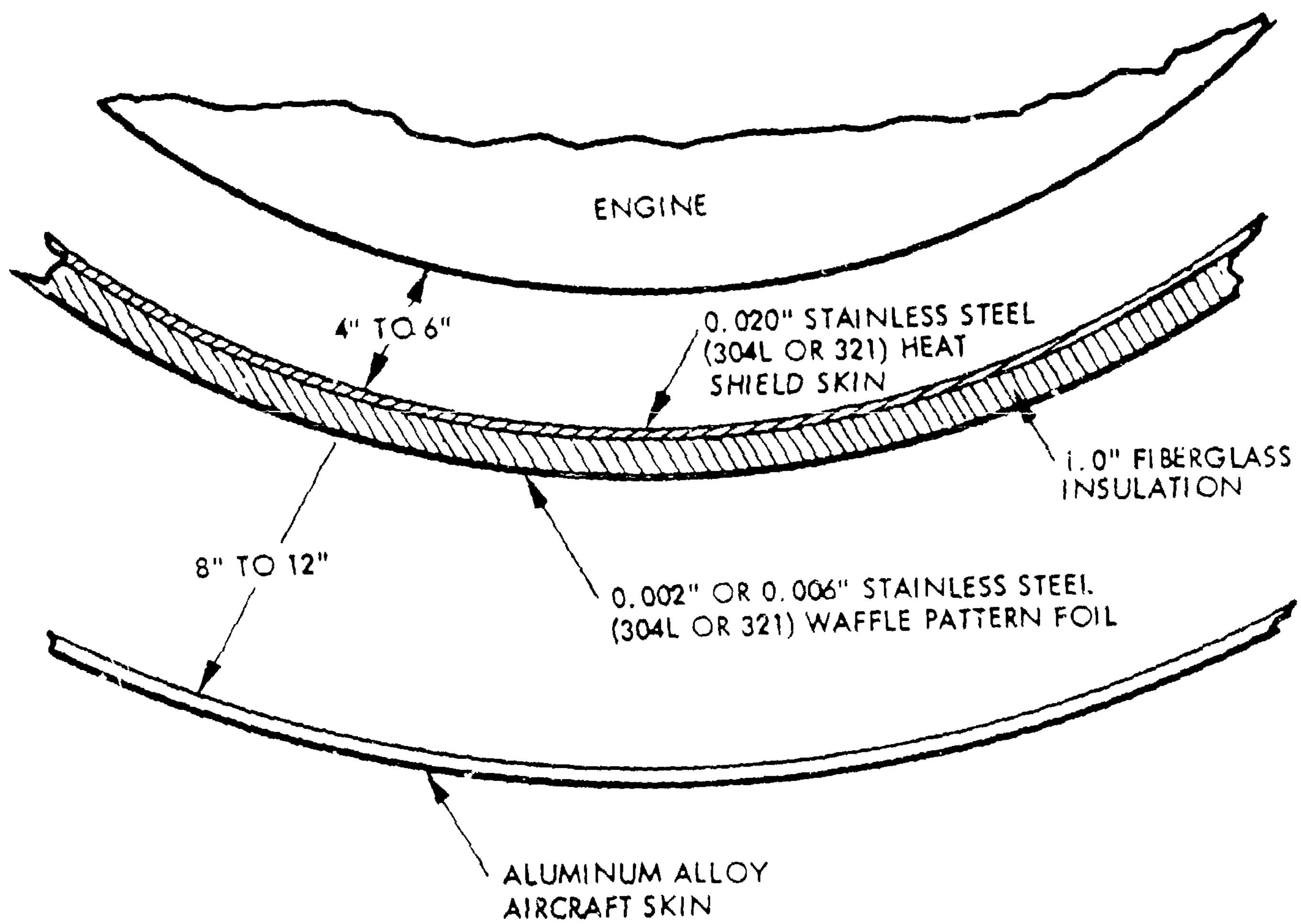


FIGURE 5.1 ENGINE SHROUD CONFIGURATION

I. AIRBORNE WEAPONS REPAIR

A. Missile Repair at Naval Air Rework Facility (NAVAIREWORKFAC) Alameda

1. Past
2. Current
3. Future

B. Missile Facility

1. Current
2. Future

C. Repair Processes

1. Induct

a. move missiles from supply
b. bring missile into building

2. Uncan Missile

a. remove missile from can
b. tag and identify required modifications

3. Inspection

a. inspect for visual defects/log book
b. tag and identify required modifications

4. Disassembly

a. remove radome
b. remove skin
c. remove components

5. Material Access/Storage

a. retrieve modification kits
b. retrieve small parts/assemblies (spares)
c. retrieve parts from supply
d. store modification kits/material

6. Install Modifications (as required)

a. remove/modify old assemblies
b. install new assemblies/components

7. Inspect Modifications

a. physical validity
b. soldering quality

8. Test Components

   a. failure verification
   b. go/no-go testing

9. Repair Components

   a. remove out of tolerance parts
   b. replace new parts

10. Repair Verification

   a. re-test (go/no-go)

11. Component Assembly

   a. mechanical
   b. electrical

12. Stress Screening (sampling)

   a. vibration
   b. temperature

13. Paint/Metal Repair

   a. strip/sand outer skin
   b. repair dents, gouges, corrosion damage
   c. prime/paint/stencil

14. Acceptance Test

   a. go/no-go

15. Final Inspection

   a. mechanical
   b. paperwork

16. Can

   a. load missile in can
   b. load accessories

17. Ship

   a. load onto truck
   b. forward to supply

prepared by
J. Foster
NESO 373

NOTE: 35mm slides depicting representative repair processes will be presented (approx. 15)

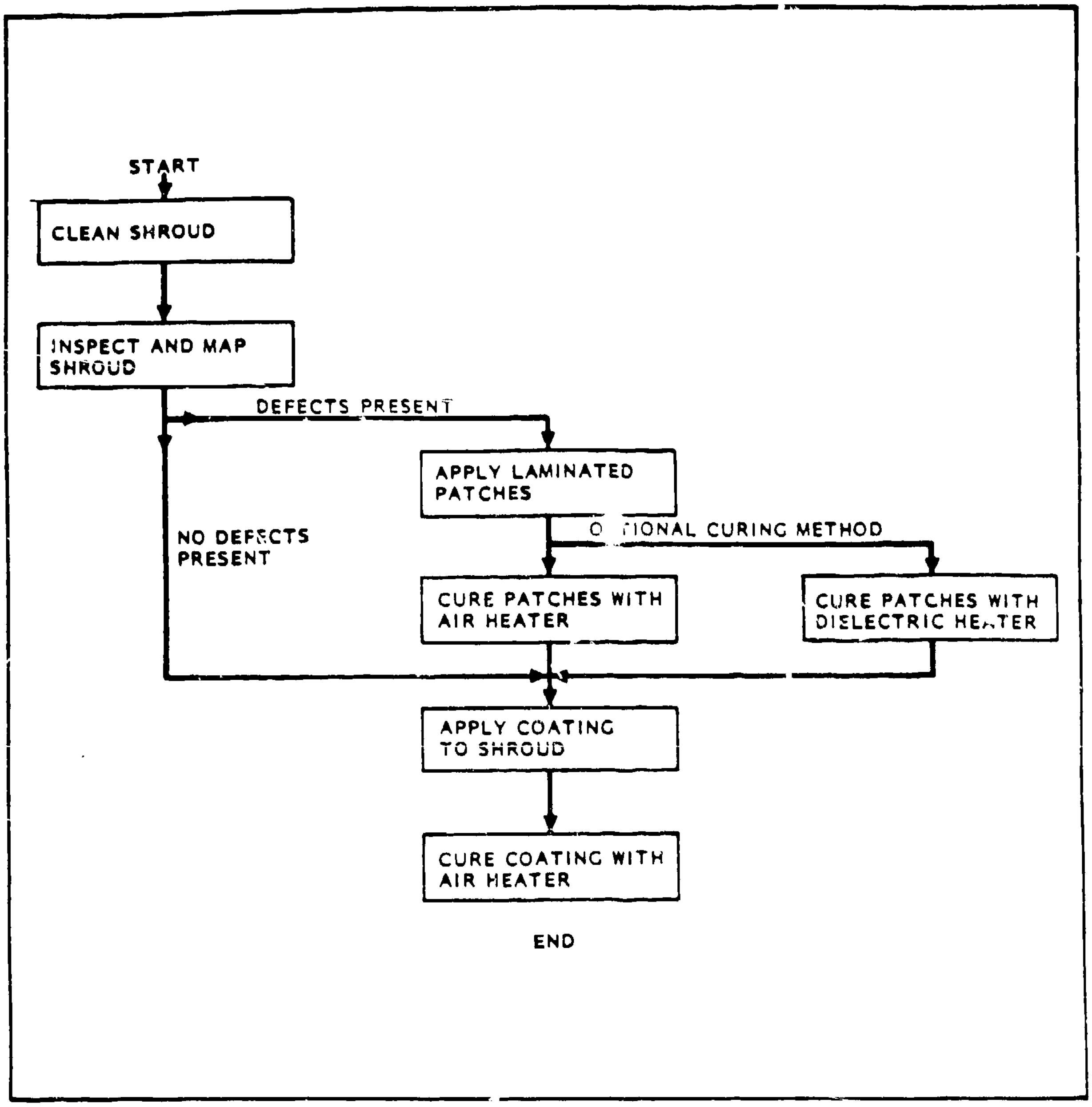


Figure 3-1 ROBOT WORK CYCLE

ROBOTIC DESIGN AND CONFIGURATION

GENERAL CONFIGURATION

A RIGID-ARM ROBOT COMBINING LINEAR AND ROTATIONAL MOTION. ROBOTIC DEVICE WILL POSITION THE VARIOUS END EFFECTORS TO WORK ON ALL PARTS OF THE INTERIOR SHROUD SURFACE.

CONTROLS

- OPERATOR STATION WITH KEYBOARD AND TV MONITOR
- 16-BIT MICROPROCESSOR
- MANUAL CONTROL BOX

SOFTWARE

- ROBOTIC PROGRAMMING LANGUAGE
- SOFTWARE ROUTINES TO MANIPULATE THE DEVICE AND OPERATE THE END EFFECTORS

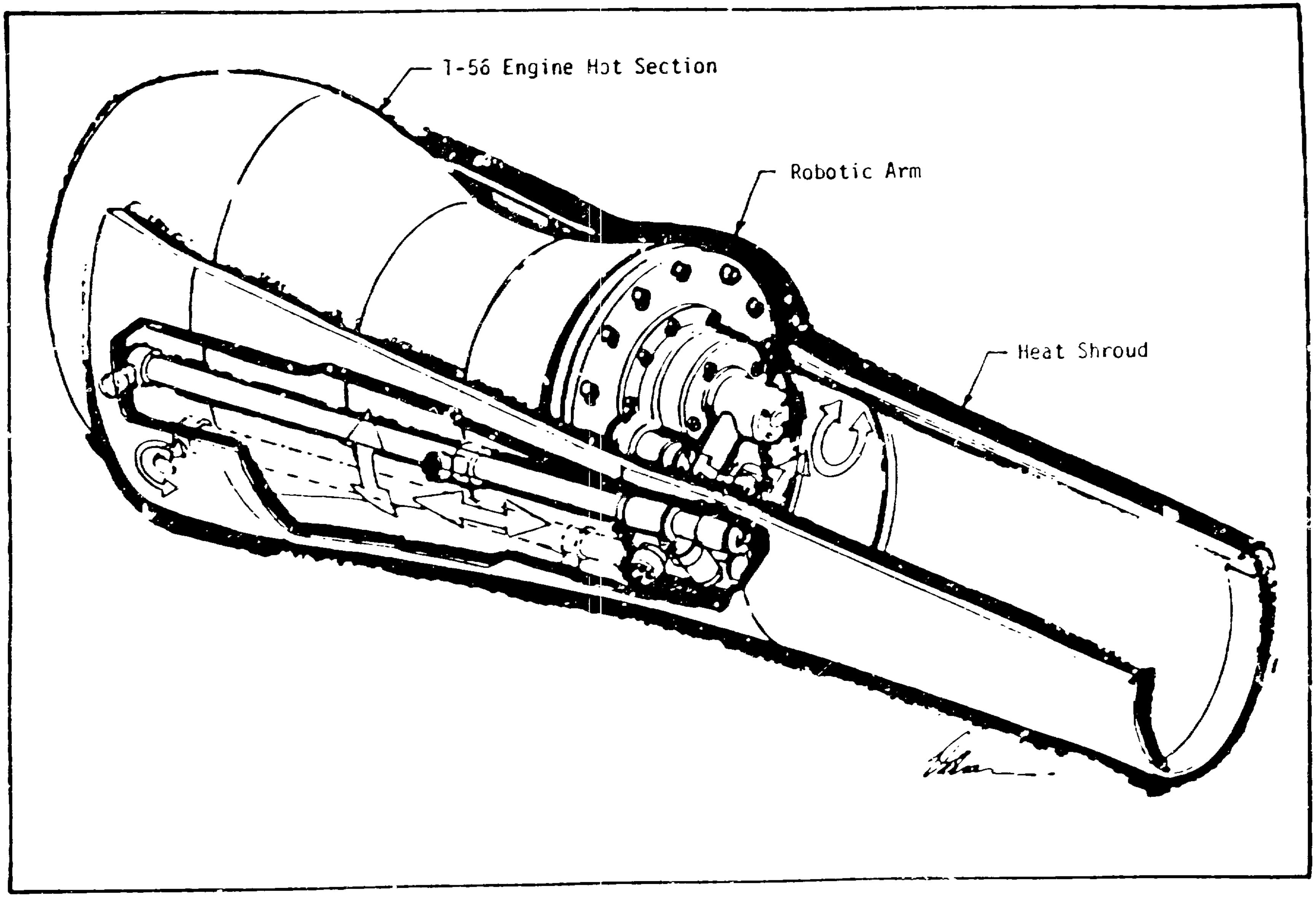


Figure 2-5 ROBOT ARM WORKING INSIDE SHROUD

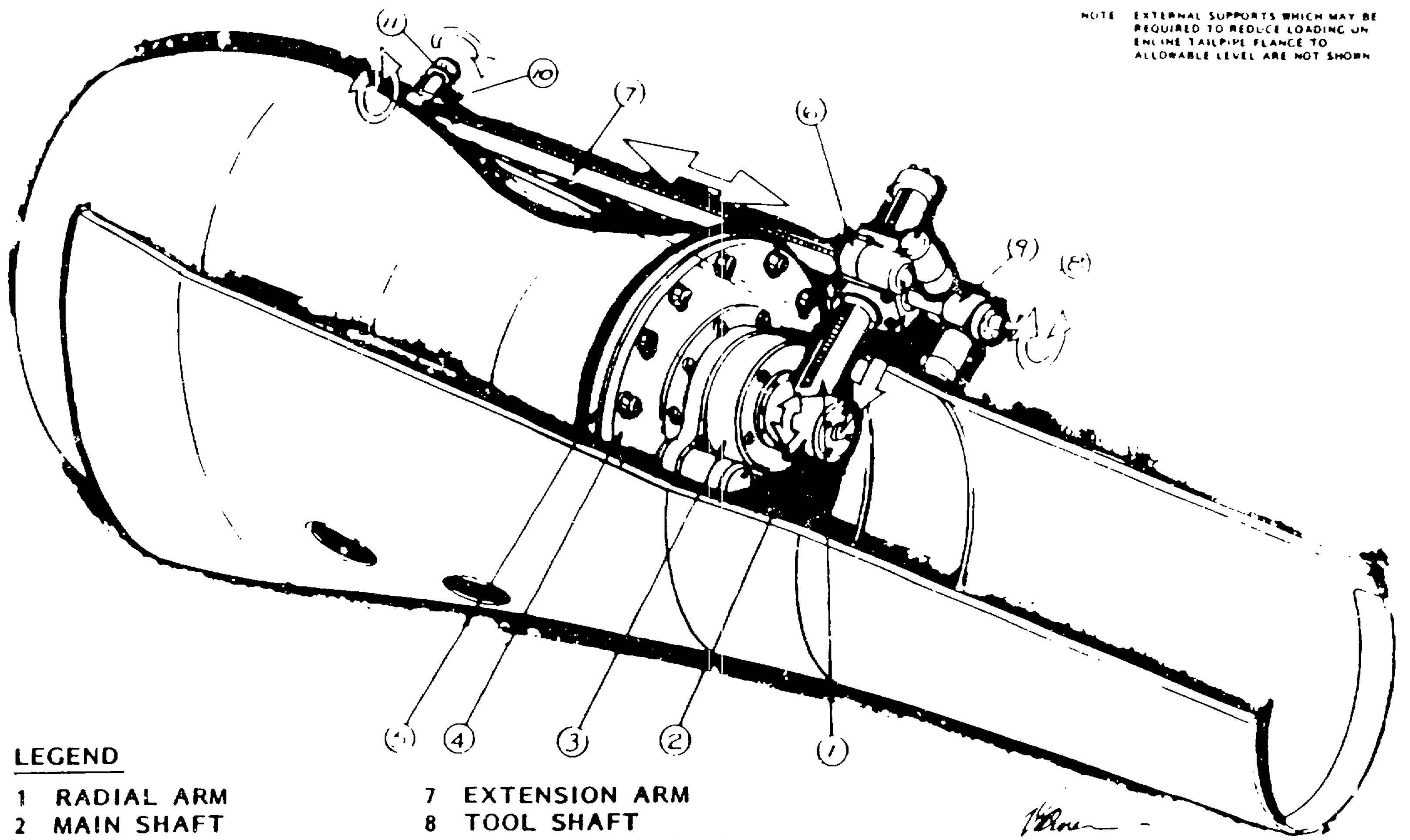


Figure 2-4 ROBOT ASSEMBLY

SPECIFIC OPERATIONS

CLEANING OF INNER SHROUD SURFACE

SPECIAL END EFFECTOR WILL APPLY A LIQUID CLEANING AGENT AND MECHANICALLY BRUSH THE SURFACE. A VACUUM HEAD AND HOSE WILL BE MANUALLY POSITIONED TO REMOVE DIRTY SOLVENT.

LOCATING DEFECTS ON SHROUD SURFACE

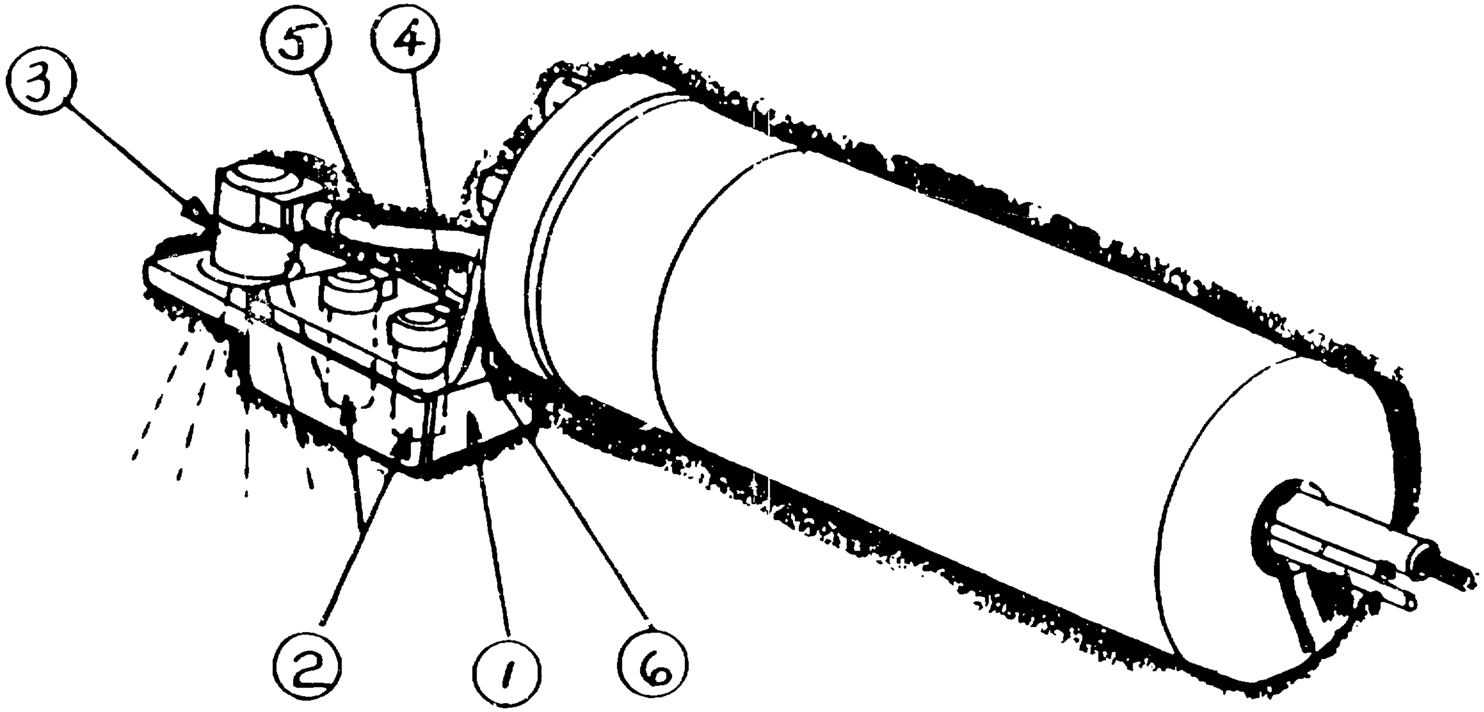
SPECIAL END EFFECTOR WILL HOLD TWO (2) DEFECT DETECTORS AND A VIEWING HEAD. DEFECTS WILL BE SIGNALED BACK TO THE OPERATOR ALONG WITH A VISUAL IMAGE OF THE SURFACE.

PATCH APPLICATION

SPECIAL END EFFECTOR WILL HOLD A STEEL FOIL PATCH WITH A VACUUM CUP, THEN PRESS ON WITH SPONGE RUBBER FIXTURE. A SECOND END EFFECTOR WILL HOLD PATCH DOWN DURING CURING PROCESS.

SHROUD COATING

- SURFACE TO BE CLEANED
- SHROUD COATED WITH A CORROSION RESISTANT MATERIAL
- COATING CURED WITH A HEATED AIR SYSTEM



LEGEND

1 NYLON BODY
2 DEFECT DETECTORS
3 VIEWING HEAD
4 ELECTRIC CABLE
5 FIBEROPTIC CABLE BUNDLE
6 LEAF SPRING

Figure 2-6 SCANNING HEAD EFFECTOR

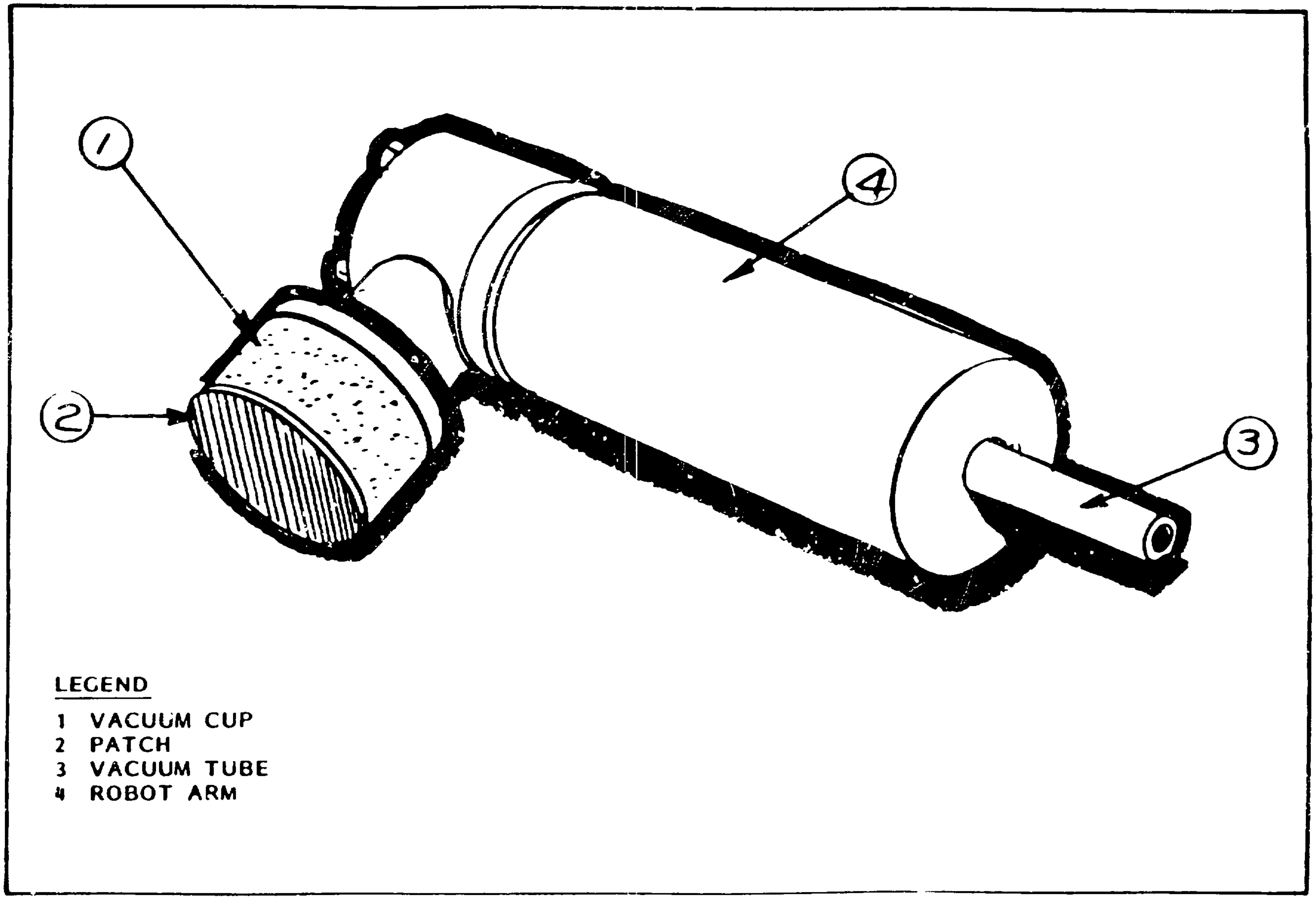


Figure 2-7 PATCH PLACEMENT EFFECTOR

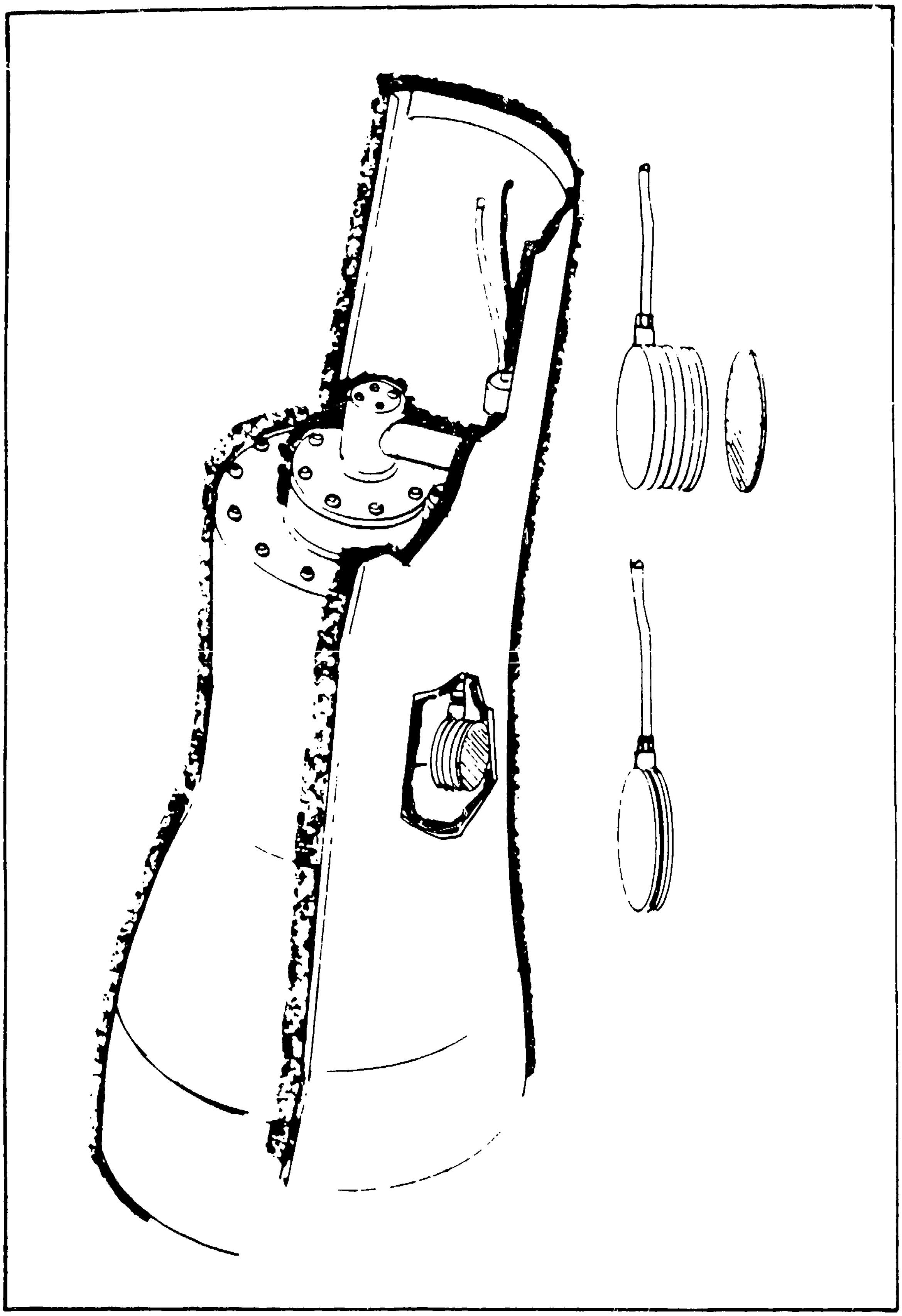


Figure 2-9 AIR BAG CLAMPING PATCH

"ON AIRCRAFT" REPAIR OF P-3 ENGINE SHROUDING

PROBLEM

A PRIMARY COST ASSOCIATED WITH REWORK OF COMPLETE AIRCRAFT COMPONENTS RESULTS FROM THE LACK OF REPAIR OR PATCHING PROCESSES THAT CAN BE PERFORMED WITHOUT REMOVAL OF DAMAGED COMPONENTS FROM THE AIRCRAFT. FOR ROUTINE OF P-3 ENGINE SHROUDS AT NARF ALAMEDA, ENTIRE ENGINES MUST BE SEPARATED FROM THE AIRCRAFT TO FACILITATE REMOVAL OF THE SHROUDS.

OBJECTIVE

THE OBJECTIVE OF THIS PROJECT IS TO PROVIDE PROTOTYPE EQUIPMENT AND PROCEDURES FOR "ON AIRCRAFT" REPAIR OF P-3 ENGINE SHROUDS. SUCCESSFUL EXECUTION OF THIS PROJECT WILL INVOLVE USE OF ONE OR MORE HIGH TEMPERATURE (UP TO 600°F) ADHESIVE SYSTEMS WITH ROBOTIC EQUIPMENT FOR CLEANING, INSPECTING, PATCH APPLICATION, PATCH CURING, AND COATING OPERATIONS.

APPROACH

THE APPROACH OF THIS PROJECT IS TO DEVELOP A SUITABLE ROBOTIC DEVICE, CLEAN THE INNER SHROUD SURFACE, LOCATE THE DEFECTS ON THE SHROUD SURFACE, PATCH THE DEFECTS AND APPLY A CORROSION - RESISTANT AND CRACK - RETARDANT COATING.

ROBOTIC DESIGN AND CONFIGURATION

GENERAL CONFIGURATION

PRELIMINARY ANALYSES INDICATE THAT A RIGID-ARM ROBOT COMBINING LINEAR AND ROTATIONAL MOTIONS SHOULD SATISFY THE REQUIREMENTS. NEW TYPE OF ROBOT FEATURING A FLEXIBLE ARM WILL BE CONSIDERED. ROBOTIC DEVICE WILL POSITION THE VARIOUS END EFFECTORS TO WORK ON ALL PARTS OF THE INTERIOR SHROUD SURFACE AROUND THE ENGINE.

CONTROLS

CONTROLS CONSIST OF AN OPERATOR STATION, WITH KEYBOARD AND TV MONITOR, A 16-BIT MICROPROCESSOR, AND A HAND-HELD MANUAL CONTROL BOX.

SOFTWARE

SOFTWARE FOR THIS SYSTEM WILL UTILIZE COMPUTER LANGUAGE KNOWN AS ROBOTIC PROGRAMMING LANGUAGE, DEVELOPED BY THE STANFORD RESEARCH INSTITUTE (SRI). SOFTWARE ROUTINES WILL MANIPULATE THE DEVICE AND OPERATE THE END EFFECTORS.

SPECIFIC OPERATIONS

CLEANING OF INNER SHROUD SURFACE

INNER SHROUD SURFACES WILL BE CLEANED BY CHEMICAL ACTION OF A LIQUID CLEANING AGENT AND MECHANICAL ACTION OF A ROTATING BRUSH. SPECIAL END EFFECTORS WILL BE DESIGNED TO APPLY THE LIQUID CLEANING AGENT AND MECHANICALLY BRUSH THE SURFACE. A VACUUM HEAD AND HOSE TO REMOVE THE DIRTY SOLVENT WILL BE MANUALLY POSITIONED.

LOCATING DEFECTS ON SHROUD SURFACE

AN END EFFECTOR WILL BE DESIGNED CONSISTING OF A NYLON BODY TO SUPPORT TWO DEFECT DETECTORS AND A VIEWING HEAD. DEFECT DETECTORS WORKING ON THE EDDY-CURRENT PRINCIPLE WILL DETECT SMALL CRACKS IN THE METAL. FLEXIBLE ELECTRIC CABLES CARRY SIGNALS BACK TO THE MICROPROCESSOR. VIEWING HEAD IS A FIBER SCOPE WITH A CO[illegible] OPTIC FIBER BUNDLE CONTAINING BOTH A LIGHT SOURCE AND IMAGE-TRANSMISSION FIBERS. BY VISUALLY OBSERVING THE DEFECTIVE SURFACE ON A TV MONITOR A DECISION CAN BE MADE TO REPAIR THE SHROUD WITH A ROBOT TO REMOVE THE SHROUD FOR REPAIR.

PATCH APPLICATION

THE PATCH USED IN [illegible] PROCESS IS A LAMINATED PATCH CONSISTING OF THREE LAMINATIONS OF STEEL FOIL. AN END EFFECTOR WILL BE DESIGNED WITH A RESILIENT VACUUM CUP FOR HOLDING THE PATCH AND A SPONGE RUBBER FIXTURE TO PRESS THE PATCH DOWN AND FORM IT SO THAT IT FITS SNUGLY AGAINST THE SHROUD. TWO DIFFERENT METHODS OF CURING THE PATCH ADHESIVE WILL BE CONSIDERED: DIELECTRIC HEATING AND HOT-AIR HEATING. DURING THE CURING PROCESS SEVERAL METHODS WILL BE CONSIDERED FOR HOLDING THE PATCH DOWN. THESE POSSIBLE ALTERNATIVES INCLUDE: VACUUM BAGS, AIR BAGS, AND SPRINGS.

SHROUD COATING

THE PURPOSE OF COATING THE INNER SURFACE OF THE SHROUD IS TO PROTECT THE METAL AGAINST CORROSION AND INHIBIT THE FORMATION OR PROPAGATION OF CRACKS IN THE METAL. PRIOR TO COATING, THE SURFACE WILL BE CLEANED AS PREVIOUSLY DISCUSSED. A COATING MATERIAL WILL BE APPLIED BY AN AIRLESS SPRAY NOZZLE OR A PRESSURE-FED ROLLER APPLICATOR. CURING OF THE SHROUD COATING WILL BE ACCOMPLISHED BY A HEATED AIR SYSTEM.

CURRENT ROBOTICS APPLICATIONS-METAL SPRAY COATING AT NARF CHERRY POINT

NAVAL AIR REWORK FACILITY

BY: J. O'BRIEN

PROCESSES OBSERVED

STRIPPING AND CLEANING

PAINTING

METAL SPRAY COATING

GRIT BLASTING

WELDING

PLATING

SOLDERING

BONDING

NC MACHINING

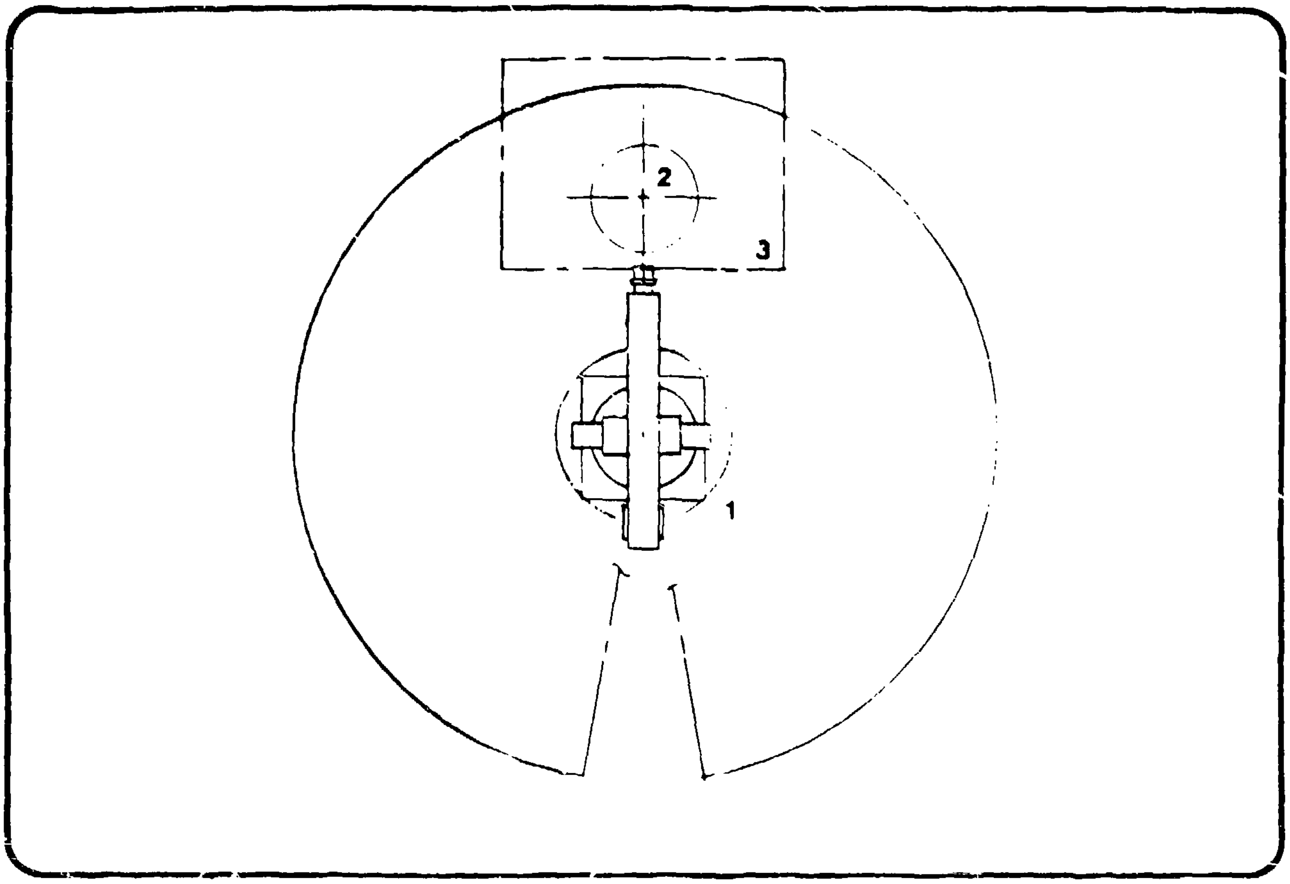
PROCESSES IDENTIFIED AS CANDIDATES FOR ROBOTICS

THE TWO MOST PROMISING CANDIDATES:

- METAL SPRAY COATINGS
- HELICOPTER ROTOR BLADE PAINTING

IDENTIFIED AS TECHNICALLY FEASIBLE, BUT LESS PROMISING:

- GRIT BLASTING OF ENGINE PARTS
- GRIT BLASTING AND PAINTING OF REUSABLE CONTAINERS
- STRIPPING OF DRUMS AND PROPTANKS



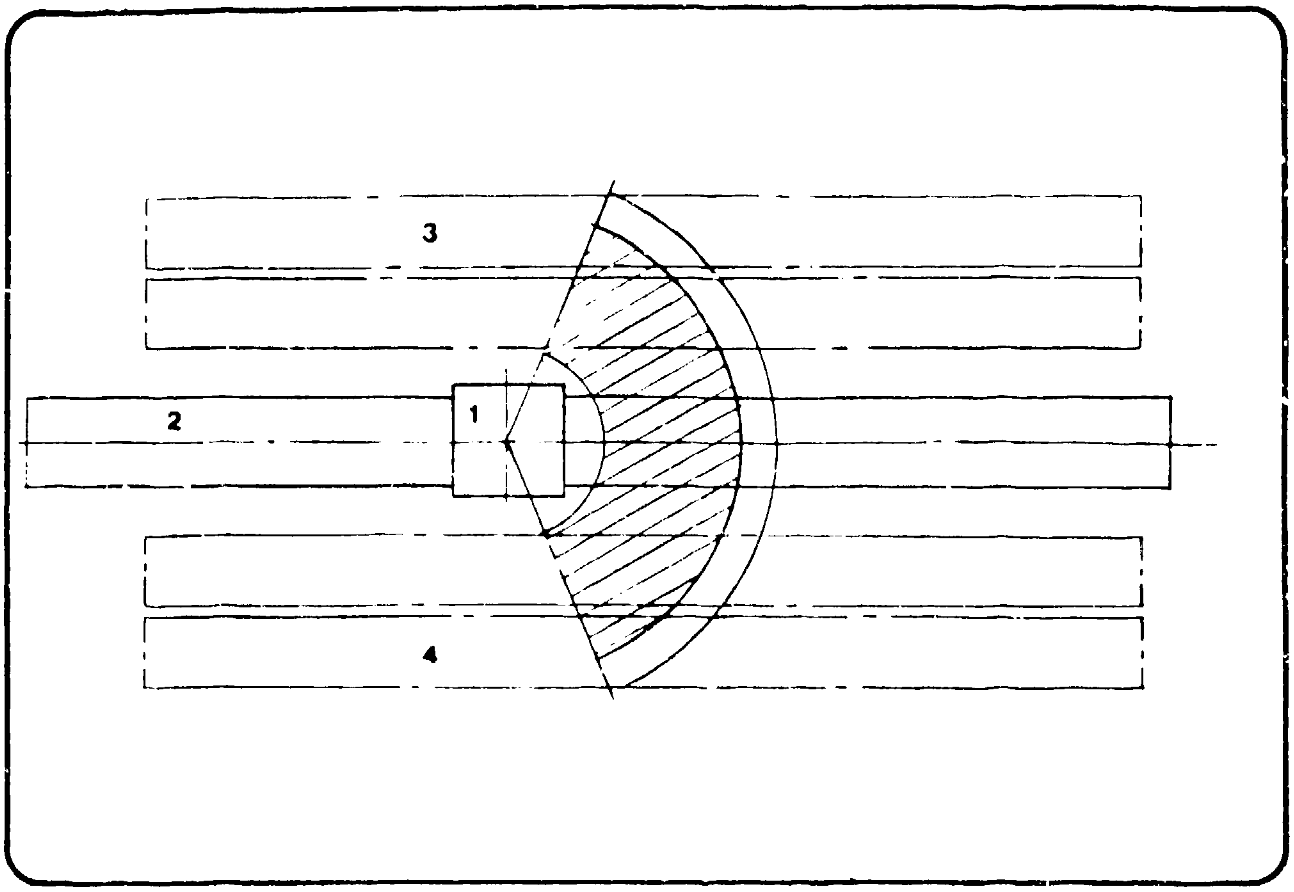
PROPOSED METHOD:

Metal Spray Coating

(1) The robot (1) metal spray coats the part in the turntable (2) which is in the existing spray booth (3).

(2) An operator unloads and loads the part into the fixtures on the turntable.

Sketch 1



PROPOSED METHOD: **Helicopter Rotor Blade Painting**

(1) Robot (1) on traverse track (2) paints helicopter blades (3) on one side of the robot.

(2) Robot then paints blades on other side (4) as it returns on the track to its original position.

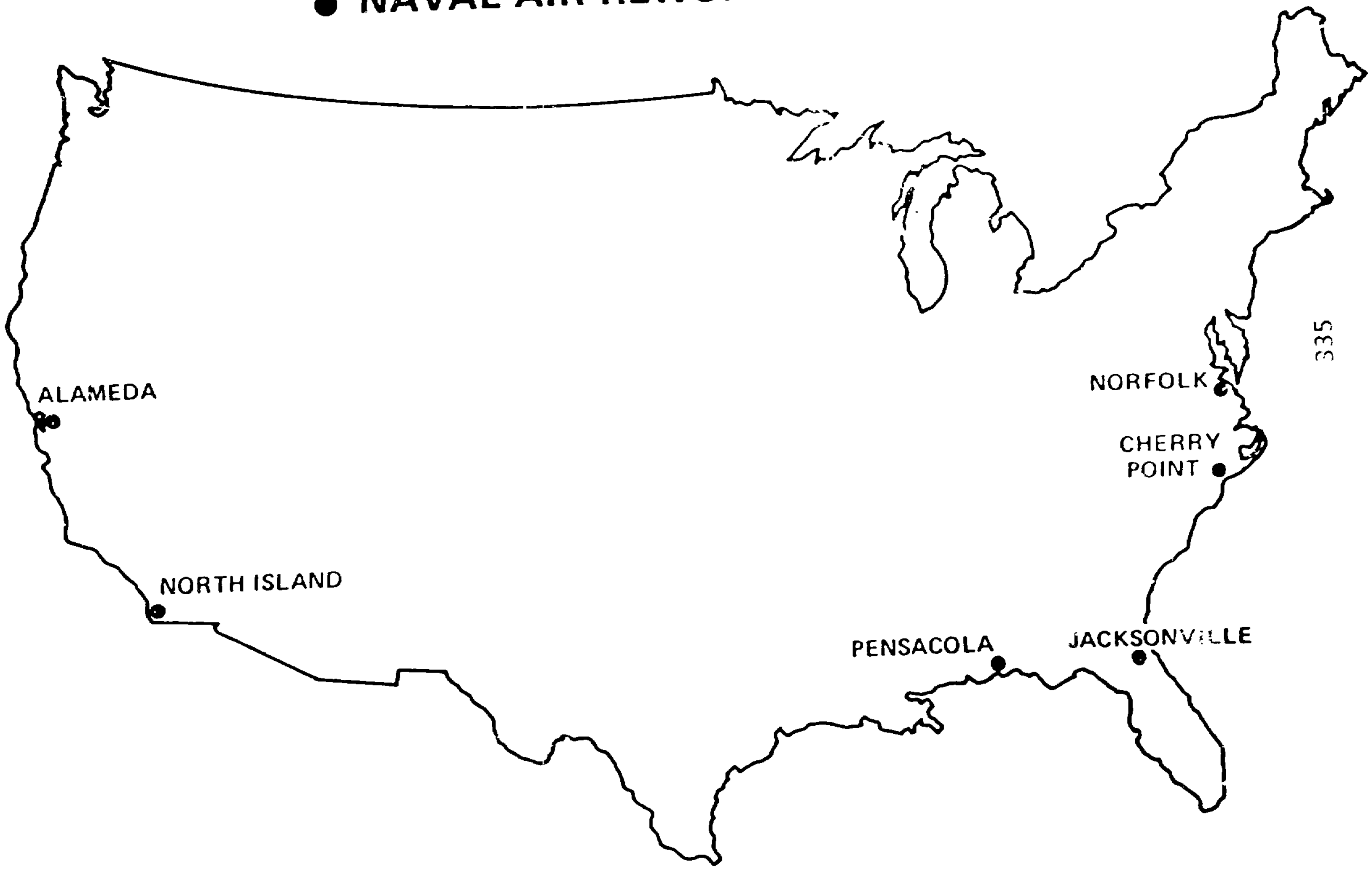
Sketch 2

CURRENT AIR DEPOT ROBOTICS PROJECTS

NAVAL AIR REWORK FACILITY, NORTH ISLAND

BY: GERALD TIETJE

• NAVAL AIR REWORK FACILITIES



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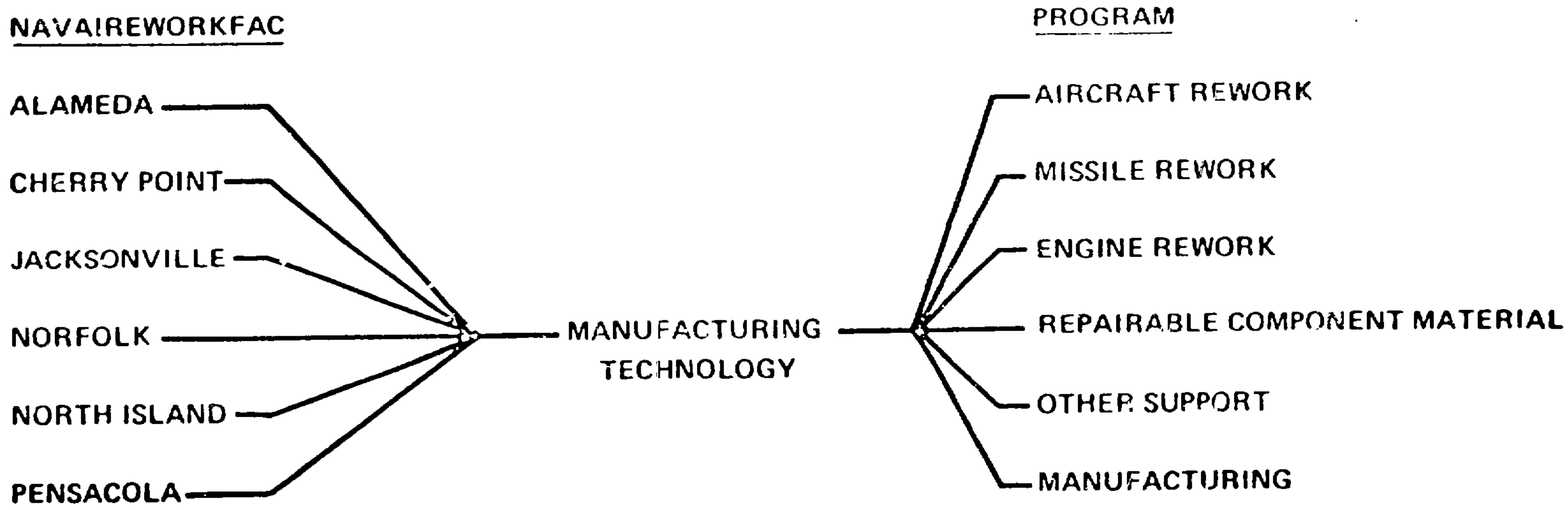
• STUDY COVERAGE



MT

- **WHAT IS A COST DRIVER?**
  - ANY PROCESS, FUNCTION OR PART WHICH CONTRIBUTES SIGNIFICANTLY TO THE COST OF AN OPERATION.
- **WHY IDENTIFY COST DRIVERS?**
  - REDUCE COSTS/INCREASE PRODUCTIVITY
    - APPLY KNOWN ALTERNATIVES
    - IDENTIFY DEVELOPMENT OPPORTUNITIES

MT

FUNCTIONAL CATEGORY COST RANKINGS

RANK	CATEGORY	PERCENTAGE LABOR	PERCENTAGE MATERIAL
1.	ELECTRICAL/ELECTRONIC	20%	16%
2.	DISASSEMBLE/ASSEMBLE	17%	13%
3.	SHEET METAL	14%	6%
4.	TESTING	7%	3%
5.	MACHINING	6%	7%
6.	HYDRAULIC/PNEUMATIC	5%	12%
7.	STRIP/FINISH/PAINT	4%	1%
8.	EXAMINATION/EVALUATION	4%	1%
9.	CALIBRATION	3%	2%
10.	MISC. – GROUND SUPPORT EQUIPMENT	2%	3%
11.	MISC. – ARMAMENT	2%	4%
12.	PACKING/PRESERVATION	2%	1%
13.	CLEAN, CHEMICAL	1%	*
14.	MISC. – FUEL CONTROLS & ACCESSORIES	1%	3%

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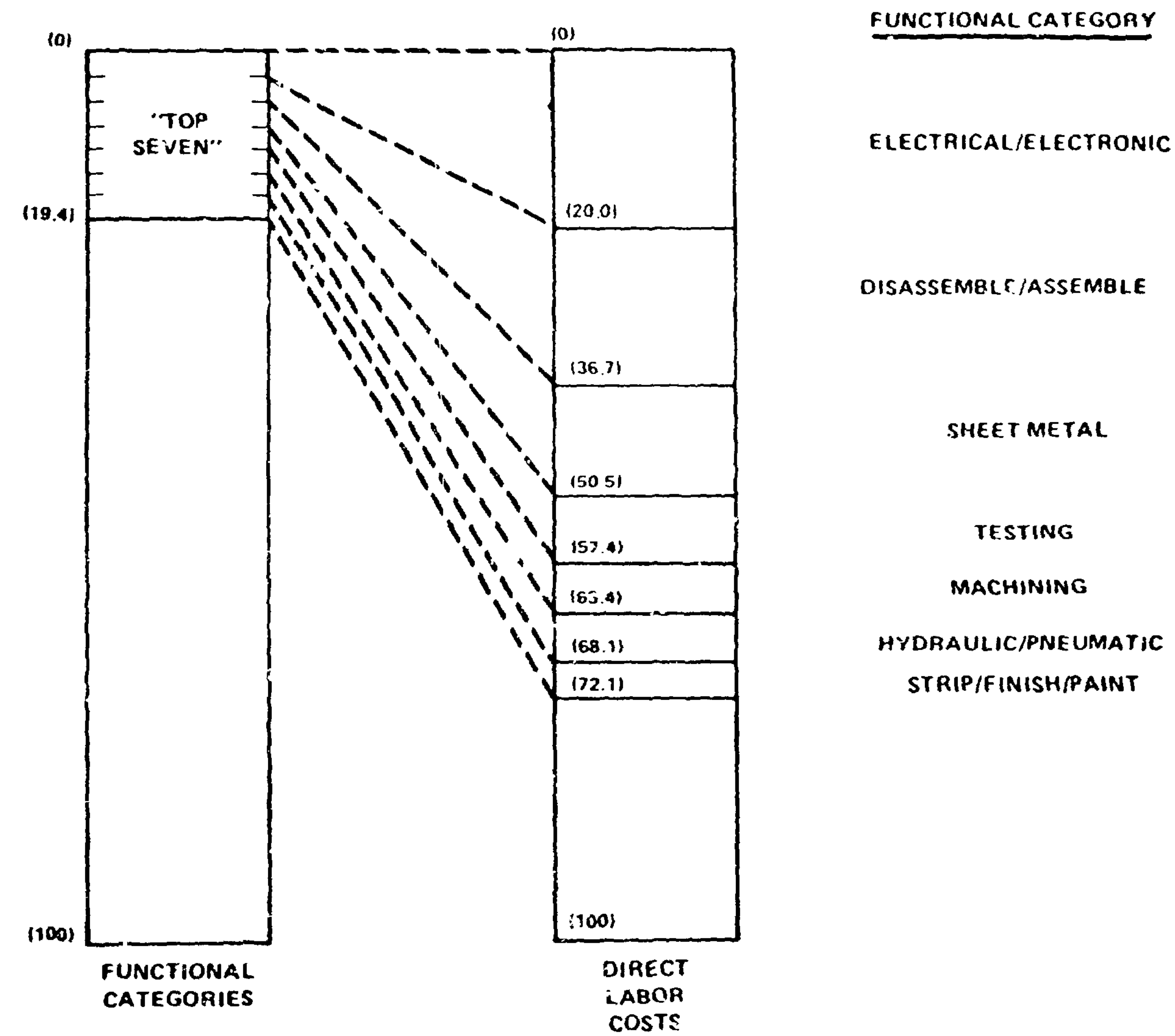
DIRECT LABOR
FUNCTIONAL CATEGORY COST DRIVERS
(JUL 77 – DEC 77)



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MT

- **RECOMMENDATIONS:**

  – LOCAL NAVY AIR DEPOT MANAGEMENT INITIATE MT PROJECTS ADDRESSING DIRECT LABOR FOR:

  - ELECTRICAL/ELECTRONIC
  - DISASSEMBLE/ASSEMBLE
  - SHEET METAL
  - TESTING
  - MACHINING
  - HYDRAULIC/PNEUMATIC
  - STRIP/FINISH/PAINT

  – PROTOTYPE EACH FUNDED MT PROJECT AT ONE NAVY AIR DEPOT BEFORE EXPORT TO OTHERS

ROBOTIC DERIVETER

APPLICATION

- REMOVAL OF NON-THREADED FASTENERS IN AIRCRAFT
  - CENTER WING SECTION
  - OUTER WING PANELS
  - HORIZONTAL/VERTICAL STABILIZERS

NOTE: COST DRIVER #2

SPECIFICATIONS

- ACCURACY $\pm$ .005 INCH
- 6 DEGREES OF FREEDOM

343

FEATURES

- VISION SYSTEM
- EDDY CURRENT CAPABILITY
- ADAPTIVE CONTROL
- AUTOMATIC TOOL CHANGING
- COLLISION AVOIDANCE
- USER FRIENDLY SOFTWARE
- MOBILITY

AUTOMATED AIRCRAFT PAINTING SYSTEM

345

BENEFITS

- REDUCED DIRECT LABOR COST
- INCREASED TOOL LIFE
- POTENTIAL ADAPTATION FOR RIVETING
- PAYBACK IN LESS THAN 4 YEARS

346

APPLICATION

- PAINTING AIRCRAFT & SELECT COMPONENTS
  - FIXED WING AIRCRAFT
  - ROTARY WING AIRCRAFT
  - WING TANKS
  - MOBILE FACILITIES

NOTE: COST DRIVER #7

SPECIFICATIONS

- ACCURACY ±.31 INCH AT END EFFECTOR
- REPEATABILITY ±.28 INCH AT END EFFECTOR
- WORK ENVELOPE (100'x70'x19')
- DEVELOPED OPERATIONAL PROGRAMS

348

FEATURES

- LARGE-SCALE OVERHEAD ROBOTIC SYSTEM
- COLLISION AVOIDANCE DEVICES
- USER FRIENDLY SOFTWARE
- PROGRAMABILTY

349

AUTOMATED WIRE HARNESS MANUFACTURING SYSTEM
NAVAL AIR REWORK FACILITY, NORFOLK
BY: WILLIAM MAXWELL

KITTING

Wire marking
Kitting

HARNESS FORMATION

Routing
Tying
End termination

FINISHING

Potting
Braiding
Backshells

350

AUTOMATED WIRE HARNESS MANUFACTURING SYSTEM
NAVAL AIR REWORK FACILITY, NORFOLK
BY: WILLIAM MAXWELL

KITTING

- Wire marking
- Kitting

HARNESS FORMATION

- Routing
- Tying
- End termination

FINISHING

- Potting
- Braiding
- Backshells

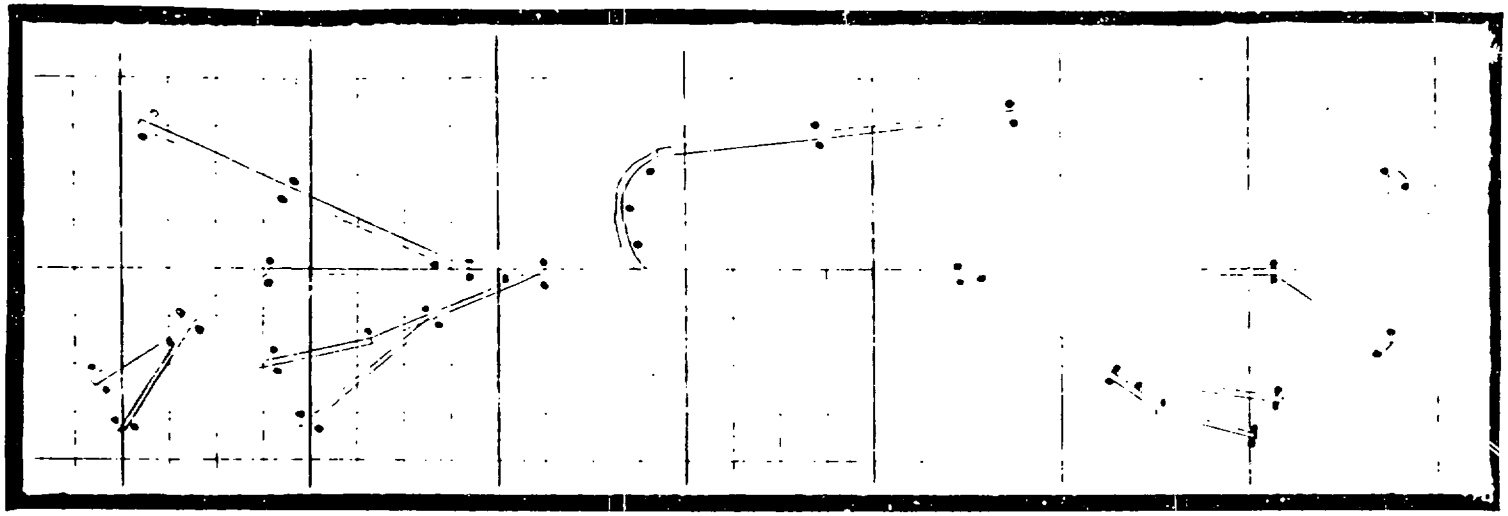
350

WIRE MARKING

- PRINTED SLEEVES
- HOT STAMP
- INK JET

KITTING

HARNESS FORMATION



ROUTING

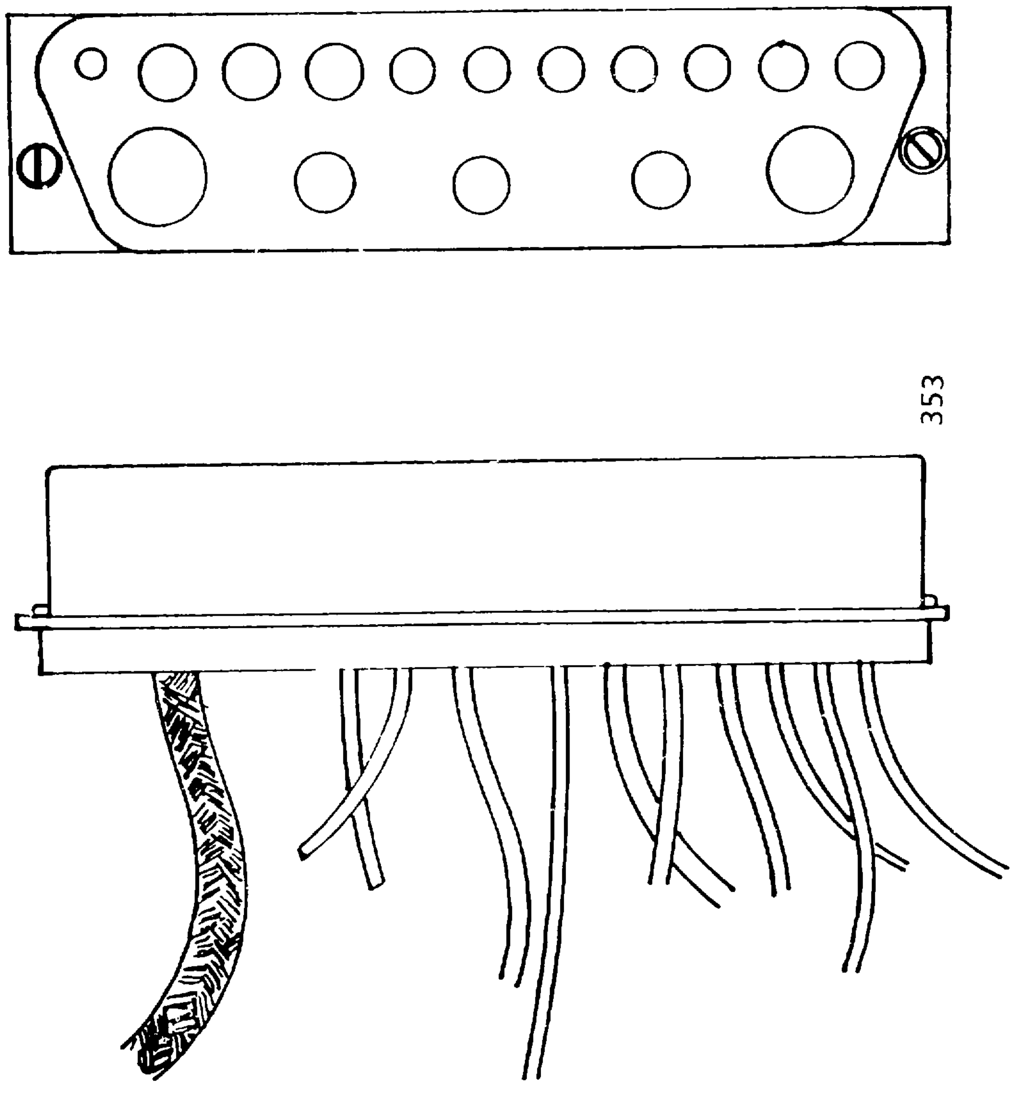
TYING

END TERMINATION

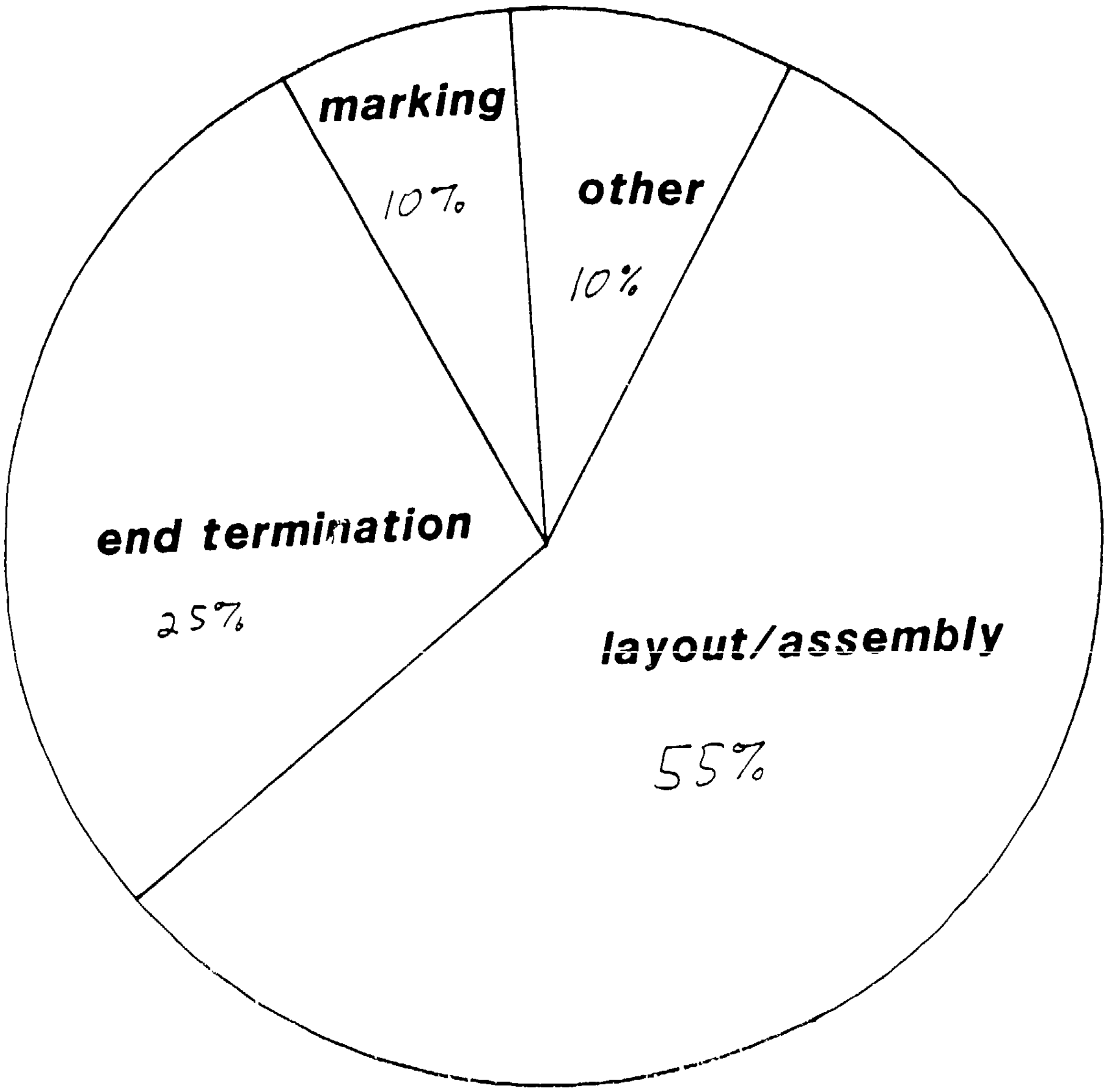
352

TERMINATION OF WIRE ENDS

- -cut
- -strip
- -crimp on pins
- -insert pins into connector



FINISHING
BRAIDING
STEEL
NOMEX
POTTING
TESTING
CONTINUITY
INSULATION


marking
10%
other
10%
end termination
25%
layout/assembly
55%

--ABSTRACT--

PROPELLER MANUFACTURING AT PHILADELPHIA NAVAL SHIPYARD

By: J. O'Hagan

Philadelphia Naval Shipyard has responsibility for the entire production process for submarine propeller manufacturing. This includes pattern development, propeller molding and casting, bulk metal removal, final finishing, measuring, and certification. Propeller design data is computer-processed to assist in pattern development, NC machining gauge manufacture, and certification. Yet, the remainder of the operation is accomplished manually, with grinding, welding, polishing, and final inspection being very labor intensive. 500 measurements are effected on the average production blade, some with tolerances to .01 inch. Repeatability, accuracy, etc. are always a problem. Some blades weigh as much as 500 tons.

The project described by the speaker automates many of the human labor operations. The equipment (Cinncinati T3 robotics and associated components) is coming on line in 1984-85. Laser optics are used in the in-process measurement process, and the metal removal and shaping (chipping, grinding, welding, etc.) are all done under computer control, as are the robotics positioning and rotary fixturing. The SCAN rate of the propeller surface exceeds 60 feet/hour of precision measurement and provides a data base for subsequent repair operations, casting analysis, etc. The quality and uniformity of the product coupled with the ability to respond to design changes and production requirements were cited as principal advantages of the new system. The labor cost savings were cited as substantial. In the planning stage is a four-cell manufacturing island which will simultaneously measure and grind to finish a number of different propellers for the various Navy submarine classes.

--ABSTRACT--

NAVY WEAPONS CENTERS AND ORDINANCE ACTIVITIES ROBOTICS PROJECTS

By: J. Johnson

Naval Sea Systems Command
Industrial/Plant Property Support Office

Robotics is not a new technology to the Naval ordnance community. The ordnance activities in the Navy initiated a robotics ammunition handling project in 1956, in a hazardous environment. Another notable application utilized an ordnance manupulator in another hazardous handling area (Hawthorne) in 1975. However, budget cuts have severely affected the ordnance activities automation programs. In the past year, modernization funds for these activities were cut from $48M to a total of $12M for all nine of the Navy activities. Yet, some progress has been made. Ammunition handling, painting, welding, and explosive ordnance disposal (utilizing an odetics robot) are all current application areas under development in these activities.

NEO ROBOTIC APPLICATION DEVELOPMENT AT LETTERKENNY ARMY DEPOT

THE APPLICATION OF ROBOTICS TO AGRICULTURAL BLAST CLEANING

LETTERKENNY ARMY DEPOT

JERRY NITTERHOUSE/STEVEN KALABOKES

Abstract

Robotics can make a potentially crucial contribution in the area of agricultural blast cleaning. To date, no such application of robotics exists, although, pending the survivability of the system within this harsh environment, robotics appear to be a natural extension to this process due to the hazards and the physical endurance requirement posed to the human operator. Letterkenny is committed to developing a working blast cleaning system to insure worker safety and readiness requirements. This paper reviews all of the basic input that has been uses to develop the specifications for the solicitation package which will be subsequently used to procure and install such a system.

INTRODUCTION

The decision to robotize the agricultural blast cleaning operation at Letterkenny is founded on the inefficiency of the current process as well as to the hazards ~~that are~~ posed to the human operator. The worker is subjected to excessive heat ~~conditions~~ as high as 120 degrees F in the summer ~~months~~, humidity conditions as high as 90% ~~percent~~ saturation, high noise levels and poor ventilation. Moreover, aerosols are generated which create an atmosphere conducive to explosion with the aid of an ignition source.

Paint tenacity, because of its irregularity over the entire work surface, has relegated the blast cleaning process to a manual operation; however with the growing concern for productivity improvement and for reasons cited above, it was felt necessary to automate the operation and remove the human operator from the booth. The extension of robotics to this application was deemed natural due to the robots ability to work in hazardous environments.

DISCUSSION

Process Comparison: Present

M109 and M110 Howitzer hulls and turrets must be blast cleaned to remove old paint and rust from metal surfaces prior to prep and final painting. Walnut shells are impelled against the vehicle surface at forces ranging from 110 to 150 PSI. Because of the varying tenacity of the old paint at different areas along the vehicle, the removal rate differs at any given point on the surface of the vehicle until bare metal is visible; he then moves the nozzle to the next area to continue the process. The operator holds the nozzle with one hand and the trigger with the other while he combats the reactant forces of the blast hose to maintain his stance. Bulky protective clothing must be worn by the operator to protect him from the harsh environment. Although the protective clothing is necessary from

the standpoint of safety, it contributes further to the heat factor and physical exhaustion of the operator.

The process involves two operators per 8 hour shift, 2 shifts per day. One worker blast cleans items within the booth and a second man observes from outside the booth to insure the safety of the operator. The second worker must also monitor the separator above the booth and make trips to the cellar to clean and check conveyor screens to assure that the blast media is returning to the booth. For this reason and for the fact that it is very difficult to observe the operator through a small glass pane in the pedestrian door, subject the operator to a potentially dangerous environment.

From the standpoint of efficiency, the workers operate at a rate of one hour in and one hour out and alternate. This lends the current method to a sufficient amount of unproductive time which contributes to high unit process time and cost. Because of the difficulty and danger involved with the current process, it was determined that a logical step to improving the method would be through the utilization of he Robotics Approach.

Robotic Application Proposed

To paint the conceptual picture, the minimum system requirements had to be examined. Five critical requirements for the development of this concept were focused upon; the work envelope requirement to accommodate all items that are to be blast cleaned within the confines of the booth; the harsh operating conditions the system shall be exposed to; a manner to assure that all items entering the booth to be processed would always be aligned with the robots reference axis since the robot is relatively "dumb"; special methods to guard the worker or anyone in the work area from inadvertently coming into contact with the robot while in operation; and a method to efficiently blast clean the areas with higher paint tenacities.

Due to the limited floor space availability, the decision has been to introduce gantry systems to utilize overhead spaces which is of low priority. The gantry would ideally provide x-y translation to increase the reach capability of the robot. The robot(s) would conceptually be continuous path servo robots with three degrees of cartesian freedom on the manipulator arm and three roll axes at the wrist to provide the necessary dexterity. Since the robots will have to be inverted, jointed arm robots were ruled out. Inverting conventional robots promotes moment of inertia problems which would reduce the load capability on the arm and accuracy and would imply higher maintenance costs. In addition, dampening devices would be necessitated due to the development of oscillation problems when heavy loads are applied at or near maximum extension for robots in this group. Furthermore, jointed arm robots require large volumes to facilitate movement and would not be capable of operating within the confining limits of the booth.

From the standpoint of work envelope requirements, spherical and conventional jointed arm robots typically have an eight foot work radius which would not suffice in this case. Furthrmore, as was pointed out earlier, jointed arm robots require large volumes of space within which to work as do spherical configured robots. Spherical and jointed arm robots would not be able to meet the work

envelope requirements within the space limitations of the booth. From the standpoint of simplicity, spherical and cylindrical configured robots are undesirable. Spherical and cylindrical coordinates must be converted to linear points in space to effect linear translational motion. This adds tremendously to he complexity of the control system and inaccuracy of command vs actual position.

The second area of consideration, operating conditions must be scrutinized. The robot(s) and gantry must be designed to withstand extreme temperatures and humidity conditions; in this case temperatures as high as 120 degrees F and humidity levels reaching 90 percent saturation. Electric servo motors must be explosion-proof certified due to the explosion environment created by the aerosols generated by the blast cleaning process. During operation, blast and coating particles will tend to contaminate the movable gantry necessitating the installation of additional fans to offset the condition. Likewise blast and coating particles will infiltrate and degrade the operation of the robot's moving parts. To remedy this problem, protective covers/shrouds would be installed to maintain the operational integrity of the system. Finally, it is anticipated that some manual touch up will be necessitated to fully complete the cleaning process. As a result, changes to the lighting conditions will have to be made to offset the loss in illumination created by the installation of the gantry.

The third area of consideration, the alignment of work items relative to the robot's reference axis is necessary to ensure the repeatability of the process. The robot is incapable of determining the actual position of the work items and would continue the operation along a pre-programmed path. The solution to this problem lies in the installation of alignment fixtures. Guide rail tracks with hard stops could be attached to the existing floor plate of the blast booth to provide repeatable positioning accuracy of + .75 inch. The guide rails could be designed to interface with M109 and M110 road arm positioning which are retained to facilitate movement throughout the work center. Similar fixtures could be designed to accommodate other items requiring processing.

The fourth area of consideration, worker safety would be tremendously impacted by removing the worker from the booth. However, the worker must be further protected from inadvertently entering the booth during actual processing. The most common method for assuring worker safety in this sense involves the installation of safety interlocks with sufficient built-in redundancy to make the system fail-safe for all practical purposes. Key fitted switches could be installed on all entrance doors of the booth to terminate both robot and blast functions when an entry is attempted. This action would initiate a pause function rather than a panic stop and would resume operation when the door is secured. Moreover, panic switches could be installed within the booth to initiate a system shutoff as an added precaution. The main concern should be to assure worker safety by introducing enough redundancy to render the system fail-safe.

The final area of consideration, efficient removal of coatings from all interior and exterior surfaces of the work items, will be a function of the control system. Ideally, programming provisions would allow the vehicle work areas to be assigned as elements of a three dimensional matrix so that a total program would be a composite of the individual vehicle sectors. This would permit the recycling of the robots to a specific matrix vehicle sector without executing

the entire program. It is antiipated that during the first operational pass, there may be large patches of surface areas that require additional processing. The recycling mode would be utilized in this case to efficiently remove coatings from these areas. Touch up operations, small localized patches, however will be performed manually. Initial programming will be done either from a lead-through teach mode or remotely by a teach pendant. Subsequent operation will have off-line capability.

AREAS OF CONCERN

Exception Handling

Generally, there are two types of exception conditions that must be dealt with -- predictable and unpredictable exception conditions. Those associated with this effort are as listed below:

Predictable Exception Conditions

- Slow loss of manipulator accuracy
- Workpiece positioning accuracy
- Unprocessed areas

The solution to these exception conditions are as listed below:

Solutions

- Scheduled calibration and maintenance
- End item reference location fixtures
- Selective vehicle sector reprocess function and manual backup system

Likewise the unpredictable exception conditions and their solutions are noted below:

Unpredictable Exception Conditions

- Intrusion of a person into the booth during operation
- Collision between manipulator and work item.
- Sensor failure
- Power outage
- Shock loadings on the manipulator arm and wrist
- Pneumatic line entanglement

Solutions

- Safety interlock system
- 360 degree cylindrical tactile contact sensors
- Dry run testing
- Non-volatile memory (EPROM) or equivalent
- Antisurge/time delay pneumatic activators
- Feed rings and auto tension cable reels

Implications of the Proposed System

The robotics approach will reduce the man-hour requirements for two reasons:

(1) The manpower requiremewnt will be reduced to one man per 8 hour shift -- only one operator is required for the automated operation.

(2) With the system availability increasing from 50 percent to 90 percent, impiies that 7.2 hours as opposed to the current 4 hours of production time (2 hours per operator).

Essentially what could once be done in 16 man-hours is predicted to be performed in a matter of eight man-hours, a fifty percent savings. Savings in operating costs are projected as 35 percent per annum through the introduction of robotics. Likewise, the human operator will be displaced from the booth making his job safer, much more satisfying, enriching, and much less strenuous.

Conclusion

The robotic approach should be a viable replacement to the manual operation pending proper design and installation. It will offer improved conditions over the current method in terms of cost, safety and readiness.

APPL   TIONS OF ROBOTICS TO SHELTER REFINISHING

TOBYHANNA ARMY DEPOT

STEVEN F. O'MALLEY

Our primary interest in robotics at Tobyhanna Army Depot is in the areas of painting and blast cleaning, and our application of this is to the refinishing of aluminum skinned communications shelters.

We are presently in the initial stages of our robotics project which is the design of the workstation. In Febru y or March of 1984, we will begin to procure the systems. A completion date fc the project is estimated at January 1985. The total cost for the project is estimated at $720,000.

We are carrying out the project in two phases; Phase I is to develop the design package, system specifications and standard operating procedures, and Phase II is to fabricate, install, test, and implement the systems.

We currently have an MMT project underway for Phase I with total funds authorized of $50,000. We are carrying out Phase I in two parts: one contract for design of a blast cleaning workstation and another contract for design of a painting workstation.

The contract for design of the painting workstation was awarded to MRC Division of Chamberlain Manufacturing Corporation, of Hunt Valley, MD.

The contract for design of the painting workstation was awarded to El Dorado Engineering of Salt Lake City, Utah.

Th expected improvements by use of robotics for blast cleaning are:

(1) The elimination of worker exposure to the unpleasant and unhealthy atmosphere of this operation, and

(2) Increased productivity by use of a more efficient and continuous process.

Our main production problem with the painting operation is the camouflage painting. In addition to paint changing, the worker has to draw the camouflage pattern on the shelter surfaces manually with chalk and number the appropriate reas according to a set pattern. This is very time-consuming. Also, the ration is unpleasant and unhealthy for workers, especially with the increasing of polyurethane paints.

The expected improvements by use of robotics for painting are:

(1) The elimination of worker exposure to the unpleasant and unhealthy atmosphere,

(2) Increased productivity by elimination of the manual camouflage tracing operation and increase equipment usage, and

(3) Improved quality due to greater consistency of application.

Eventually, we would like to interface the robotic workstations with our existing CAD/CAM System in order to facilitate off-line programming.

AD-P004 008

DEPOT MODERNIZATION

DEFENSE LOGISTICS AGENCY

BY: COLONEL THOMAS L. KIRKHAM

Believe it or not, the Defense Logistics Agency (DLA), and I'll refer to it as DLA from now on, wasn't invited to this workshop. We had to invite ourselves. In fact, you will notice I'm listed with the Air Force under the caption of, "Potential Depot Applications and Plans for the Future".

I'm certainly pleased to be here. First, I'm pleased to be here as an Air Force officer, and I'm glad for this opportunity to meet many of my Air Force friends that I haven't seen for some time. Secondly, I'm pleased to be here representing DLA, and I appreciate the opportunity to meet and talk with many of you representing the various military services.

Let me first tell you that DLA is part of DOD. In fact, in DLA all the military services (Air Force, Army, Navy, Marine Corps) are represented in key managerial and executive positions. At the present time, we have a director who is a Navy Flag Officer: His name is Vice Admiral Grinstead. His deputy for acquistion management is an Air Force Flag Officer: His name is Major General Connolly. The military positions are generally rotated from one military service to another.

I'd like to take a moment to talk about DLAs mission and how important it relates to supporting the combat services. DLA's basic mission responsibilities fall into three major categories.

1. Contracting and Supply Support.
2. Contract Administration.
3. Logistics Services.

DLA is responsible for the acquisition, storage, and distribution of over two million items used by the military services and other federal agencies. DLA manages consumable supply items such as fuels, food, clothing, medical, construction and electronic parts, many of which are in support of weapons systems. Nonconsumables are managed by the military services.

The DLA supply centers, which act as the inventory control points, are:

Defense Construction Supply Center, Columbus, Oh

Defense General Supply Center, Richmond, VA
Defense Electronics Supply Center, Dayton, OH
Defense Fuel Supply Center, Alexandria, VA
Defense Industrial Supply Center, Philadelphia, PA
Defense Personnel Support Center, Philadelphia, PA

We have six DLA Depots which support our distribution mission. Two depots are collocated with the Centers at Columbus, Ohio and Richmond, VA. Four depots are dispersed throughout the U.S. and are located at Tracy, California; Ogden, Utah; Mechanicsburg, Pennsylvania; and Memphis, Tennessee.

As chief of the Depot Operations Division, I take a lead role in managing depot modernization at DLA. Let me illustrate the organizational framework which I operate with. The Depot Operations Division is located at Headquarters, at Cameron Station, Alexandria, Virginia--just a few miles from the Pentagon. I have three branches: An Operations Branch, a Programs Branch, and a Mechanization Office. The Operations and Programs Branches are located with me at Headquarters. The Mechanization Office, which we call DMECSO (Depot Mechanization Support Office), is located at the Defense General Supply Center (DGSC) at Richmond, Virginia. DMECSO provides technical and engineering support in implementing the modernization/mechanization plan approved by DLA. The Contracting Division at DGSC Richmond has been designated as the Central Procurement Office for mechanized materials handling projects. Consequently, DMESCO, because it is located at DGSC Richmond, is ideally located to act as contracting officer's technical representative when major materials handling systems are procured for DLA. In addition, DLA has an Operations Research Office located at DGSC Richmond. It is available to provide support to DMESCO, as needed. Also, the Depot System Automation Center has personnel attached to DMECSO to work computer programs related to the automated/mechanized projects. The installation services director at Headquarters provides functional support on mechanization projects involving military construction. The installation services director programs and budgets the construction portion of the various mechanization projects and is an important player interfacing with the Corps of Engineers and the Naval Facilities Engineering Command. Recently, DMESCO has had to undertake a new mission, the modernization of defense property disposal sites. This is a major task because very little mechanization has been done at property disposal sites. They are labor intensive and sadly in need of mechanization improvements. I would like you to take note that the Depot Operations Division is the key player dealing with other functional elements. The Depot Operations Division manages the execution of the mechanization projects and provides status reporting to higher levels on a scheduled basis.

Let me go over some recent ongoing modernization initiatives within DLA:

Our current plans are to build Integrated Materials Complexes (IMCs) at Mechanicsburg, Pennsylvania; Tracy, California; and Memphis, Tennessee. At Defense Depot Mechanicsburg, our plans include a new high rise warehouse to be contructed and integrated with other warehouses.

The complex will house a new computerized mechanized Materials Handling Storage and Retrieval Facility, including receiving, storage, issuing, consolidation and parcel post shipping. the IMC is scheduled to handle 240,000 receipts and 3,100,000 issues annually, while operating on a 40 hour per week basis. The IMC will not be used to store hazardous or toxic materials.

At Defense Depot Tracy (DDTC) the project will be similar to the one being installed at Defense Depot Mechanicsburg. It will include a new high rise warehouse which will contain computer controlled storage and retrieval equipment, both manned and unmanned. In the high-rise area, large loads will be handled by rail guided cranes which interface with robot vehicles. These vehicles will be wire guided and will be programmable to follow a variety of paths and delivery points.

At Defense Depot Ogden, Utah, we are upgrading the freight packing and shipment terminal, substituting power conveyors and pallet shuttles for manual effort as currently required to move carts and handle material in the freight terminal.

At Defense Depot Memphis, Tennessee, we are expanding the freight terminal utilizing modern material handling techniques. The project includes a robot transfer device for pallet movement from conveyor to interface with robot vehicles.

The problem we have run into in our depots is that the immense variety of parts configurations and package sizes does not lend itself to robotics application. The multiple configurations and package sizes make it difficult to locate an item in a uniform manner in the storage trays so that it would be suitable for robot picking.

We have mechanized some of our bin operations areas by installing carousels for handling fast moving items. There is available on the market now a robotics picking device that withdraws the trays from the carousel and delivers them to a work station. We see some potential application of this system in our operations. White carousel is the manufacturer--it is called "Stor-Bot"--and has been installed at Western Electric, GE, Westinghouse, IBM, and Hewlett Packard.

Since DLA has . . .

DLA does not have an R&D mission, nor a maintenance mission on a major weapons system, which could lead to robotics applications. We do, however, have a mission of storing and handling hazardous materials in our depots and disposal sites, ~~consequently~~ there are some areas of potential application of robotics for the sake of safety and health of our employees. ~~In~~ conclusion: The author concludes that: (1) DLA's

1. Our investment in robotics equipment will be primarily in support of automated/mechanized materials handling systems, and (2) Since

2. DLA is oriented towards buying off-the-shelf equipment, whatever is available in robotics equipment as a proven materials handling device will be considered for application in our depots.

3. We look forward to applying such equipment in ever greater quantities in our depots.

AD-P004 009

LASER PAINT REMOVAL

-AIR FORCE LOGISTICS CENTER-
HQ AFLC/MAXT

BY: THOMAS MALLETS

AFLC is continually interested in modernizing its organic depot maintenance industrial base so as to improve aircraft turnaround rates and the Air Force war readiness posture. A costly and time consuming operation in our depots is paint removal as structures are prepared for corrosion inspection and/or damage repair and remanufacture. Current chemical methods' problems include: toxicity, induced corrosion; induced repaint debonding, low strip rates, and incompatibility with some metallic or composite materials. Since work load assessment for FY83-88 indicates AFLC will need \$125M for paint stripping, other stripper methods are being evaluated. One of the advanced techniques AFLC is supporting is the AFSC - Air Force Materials Laboratory's Automated Laser Paint Stripper program is a ~~This~~ three phase effort includes: feasibility demonstration; prototype optimization; and implementation at our Air Logistic Centers (depots) by FY88.

Major technical areas that make up the automated system include: (a) laser device with power and uptime to handle the number and size of aircraft (F-16 vs C-5A); (b) the beam transport and manipulation system; (c) controls for beam/aircraft safety, alignment, and surface condition sensors; (d) integration software; and (e) cleanup of residue products. Reliability and automation of the laser stripper approach offer many products. Reliability and automation of significant potential for reducing the time and cost/ft^2 stripped. Additionally, valuable manpower can be used in more critical areas as work loads change with systems' technology.

Following is the presentation material discussed on this subject:

LASER PAINT REMOVAL SYSTEM DEVELOPMENT

PROBLEM: PRESENT CHEMICAL STRIPPERS:
REQUIRE LARGE NUMBER OF MANHOURS
INITIATE CORROSION
ATTACK COMPOSITE STRUCTURES

OBJECTIVE: Establish Laser Paint Stripping as a viable depot maintenance production process.

G. F. Schmitt
AFWAL/MLBT
AV 785-7377
(Program Manager)

M. J. Halliwell
AFWAL/MLBT
AV 785-7377
(Tech Director)

T. J. Mallets
AFLC/MAXT
AV 787-7114
(Logistics Liaison)

AIRCRAFT ARE PAINTED FOR MANY REASONS

Protection from erosion/corrosion damage
Decorative/informative
Camouflage
Radar return suppression
IR suppression

PAINT IS REMOVED FOR THE FOLLOWING REASONS

Corrosion inspection
Damage repair
Removal of weathered paint
Change top coat system

A STRIPPING SYSTEM SHOULD MEET THE FOLLOWING REQUIREMENTS

Non-toxic
As fast as chemical stripping
Ability to remove paint from metal
Ability to remove paint from composite
Eliminate corrosion initiation
Eliminate repaint debonding
Minimum clean up cost
Low life cycle cost

LASER PAINT STRIPPING ELIMINATES LARGE NUMBER OF STEPS

Position A/C
Mask A/C
Install stripper troughing
check by painters
Flow stripper on A/C
Dwell time
Scrape off
Flow stripper on A/C
Dwell Time
Scrape off
Acid bath
Soap and water (wax removal)
Edge stripping (by hand)

Reseal A/C
Sand
Solvent wash
Chemical etch
Application of paint
Remove masking — Not required with Laser Stripping

AUTOMATED LASER PAINT STRIPPING

OBJECTIVE

Application of controlled laser removal of paint from Aircraft through intelligent automation

SCOPE OF PROGRAM

Program will address elements of laser stripping System as follows:

- Mechanical Components
- Sensing
- Automated Processing, Distribution & Control Functions
- Cost Estimates
- Prototype Construction and Demonstration

SYSTEM DESIGN CRITERIA

GENERAL

- Be capable of use from F-16 up to a C-5
- Emphasize low-risk system development
- Minimize second system cost
- Minimize R&D schedule
- Maximize efficiency of repaint cycle
- Target up-time of 85%
- Pre-programmed operation
- Fail-safe operational use
- Concurrent process inspection

SUMMARY

A system which is early in time, low in risk, with Adequate performance is preferred to one that is Development driven to achieve optimum performance.

PAINT STRIPPER ROBOTICS FOR AIRCRAFT

Utilize existing laser
Minimize robotic development
Concentrate on process development and manufacturing engineering aspects

Interact strongly with AF on expected system utilization

CONCEPTUAL SOLUTIONS

Gantry
Cyclops & modifications
Others
Component/small aircraft stripper

BENEFITS OF LASER PAINT STRIPPING

REDUCED:

- Stripping costs
- Waste disposal
- Toxicity
- Damage to aircraft substrates
- Induced corrosion

FASTER PAINT STRIPPING

EASIER STRIPPING OR COMPOSITES

AIR FORCE MATERIALS LABORATORY PLANS/PROJECTS

-WRIGHT-PATTERSON AIR FORCE BASE-
AFWAL/MLTM

BY: S. LEE

The Air Force Manufacturing Science and Manufacturing Technology projects in robotics technology have a focused objective. The goal is to provide a technology base for smart assembly in aerospace batch manufacturing making extensive use of robotics. The robotics thrust encompasses design of products for automated assembly, process planning, flexible tooling, vision, and other sensors as well as artificial intelligence. These technologies will be developed and subsequently demonstrated in a factory environment through follow-on manufacturing technology programs. In addition, the Air Force Manufacturing Technolog Program encompasses several other projects dealing with process or factory automation that involve extensive application of state-of-the-art robots. These programs are varied and include robotic grit blasting and plasma spraying, composite lay-up/assembly, NDE, turbine engine, airfoil grinding, riveting, deburring, routing, machine loading and other applications. The Air Force Technology modernizing programs managed at Wright-Patterson AFB have frequently included robotics application as a major part of the overall modernization effort.

Several of the on-going Air Force programs will contribute significantly to the robotics technology base. A three pronged program called "Advanced Robotics Systems for Aerospace Batch Manufacturing" deal with off-line programming, improved accuracy and technology demonstrations. McDonnell Douglas is the contractor for Manufacturing Control Language (MCL) enhancement, an off-line manufacturing cell control as well as an off-line programming robotic programming language, enables cell lay-out or design and robot motion programming to be accomplished and debugged computer terminal. The program can then be down loaded to the robot and cell machines when required. A 3-D vision system will be demonstrated under a program with Robot Vision Systems Inc. This effort, will provide closed-loop real time control with enhanced position accuracy. Finally, Grumman, Fairchild and McDonnell Douglas respectively will demonstrate the use of MCL in conjunction with improved vision and tactile sensor technology on selected aircraft production applications. Another major activity managed by the Air Force, but, funded through the Defense Advanced Research Project Agency is "Intelligent Task Automation". This program consists of two parallel efforts with Honeywell Inc. as the team leader on one contract with Stanford University, SRI International and Unimation as supporting contractors. Martin Marietta is conducting the other program. These

programs involve the development of a smart robot to perform complex tasks such as automated assembly. Control and sensor technology is being established that will enable the robot to perform reliably in an unstructured environment for automated assembly, munition handling and other complex tasks beyond the capability of existing robots. Other programs under Materials Laboratory direction include development of advanced manipulators, dexterous hands and kinematically redundant manipulators.

BROAD GOALS

Maintain U.S. Superiority in Technology

- Several technical advancements
- Provide mechanism for technical training

Assume U.S. Advantage in Technology Insertion

- Focus on defense applications
- Encourage maximum spin-off to commercial sector

Reduce Industry Duplication of Effort

Provide Motivation and means for industry leadership

Strategy - Major University Involvement

AFOSR Centers Excellence

- Industry/University Exchange Program
- Robotics Curriculum Development
- Interdisciplinary Team
- Research

Directly Fund Universities for Basic Research

- End-effectors
- Kinematics
- Control issues
- Actuation principles

Participation in Man Science Program

Semi-Annual Workshops

Hazardous Operations Benefits

Military Applications

- Bomb loading
- Bomb defusing
- Munitions handling

Quality Problems and Inspection Costs are Large

Expert Systems for Manufacturing

Objective: Establish and demonstrate methods/tools to construct knowledge based systems for MFG applications

Scope: Knowledge acquisition · Data Abstraction · Architecture · Feasibility

Strategy: Research in 4 areas
- Semantic Modeling
- Abstract data type
- Simulation machines
- User interfaces

Applications in 3 areas anticipated
- Planning/Control
- Man-machine distribution of tasks
- Fault diagnostics

Payoff: Reduced facility and equipment costs
Improved schedule realization and thru put
Practical MFG demonstration

Payoff (Estimates not Confirmed)

Direct Savings

- -Reduce assembly labor costs by 70%
- -Reduce scrap/rework costs by 90%
- -Reduce hardtooling by 80%

Indirect Savings

- -Double surge capacity
- -Reduce lead times by over 25%
- -Improve on-time delivery rate
- -Reduce inventories
- -Reduce upstream constraints - reduce costs by 20%

Unknown

- -Cost of new intelligent system
- -Cost of maintaining system

Intelligent Task Automation

Innovation

- -Mulit-arm coordination
- -High resolution, fast vision
- -Quasi mobile
- -Enabling technologies for assembly

Subsystem

- -Multi-arm inspection/assembly unit

Manufacturing Applications

Flexibility

- -Programming
- -Link to cad
- -Knowledge based
- -Generic end-effectors
- -Range of manipulators
- -Multiple arm coordination

General

- -Accuracy
- -Robotic design and evaluation capability
- -Kinematics
- -Actuation
- -Control

Strategy

Spike Fund Pacing Research and Development Areas

Provide for rapid technology insertion

Establish major university involvement

Encourage complimentary industry research and development

Coordinate with other government organizations/programs

Technology Insertion

Sponsor High Payoff Application Projects

- -Form industry teams
- -Provide university - research - industry links
- -Allow for industrial leadership
- -Semi-annual workshops
- -Integrate science program with follow-on manufacturing technology

Smart Assembly
State of Art

Operations are Manual

Labor Intensive

- -Skills
- -Variety of tasks

Assembly Practices Constrain Upstream Processes

Assembly Labor Comprises 40-60% of Total Aircraft Labor (e.g. 40% of F-16)

Benefits - Flexibility to Product Changes

Complete product
Changeover for wartime

Portional changeover for diversification

Integral first order for prototype production

Engineering changes

Benefits - Increasing Number and Type of Applications

Late 1970's

- Spot welding
- Spray painting
- Drill and rivet

Early 1980's

- Templateless drilling
- Arc welding
- Wire harness assembly
- Sealant application

Mid/Late 1980's

- Assembly
- Military applications

Enabling Technology Required

Rapid production rate changes
- Product changeover
- Automation of highly skilled operations

Strategy - Complimentary R&D

Workshops

Assist in establishing broad Air Force plan

Brief community on plans/programs

Seek strong Air Force commitment to 5-7 yr plan

Strategy - Pacing R&D

Environmental Sensitivity

- Vision/range
- Acoustic
- Force/touch
- Environmental modelling
- Expert system

Battlefield Applications

- -Autonomous soldier
- -Intelligent RPV's
- -Reconnaissance

Manufacturing Applications

- -Chemicals
- -Noise
- -Heat

Lack of Qualified People

University

- -5% of U.S. graduates are engineers
- -15% of Japanese graduates are engineers
- -20% of European graduates are engineers
- -40% of Eastern Block graduates are engineers
- -Japan has 6 times more engineers per capita than U.S.

Industry

- -Existing core group
- -Applications specialists are growing

Government

- -Fragmentation of limited expertise

Inflexible to Change

Operation to operation variations

Engineering changes

Product line changes

Variations in production rates

Changes in the environment

Unexpected situations

No Focused R&D on Defense Specific Needs

Spectrum of robotic devices with a continuum of operating parameters

General purpose designs

Mobility

-Assembly
-Inspection
-General purpose automation

Manufacturing Benefits

-Automation of highly skilled operations
-Highly accurate, coordinated system

Team

-Martin Marietta
-Stanford
-Erim
-VPI
-RPI
-McDonnell Douglas

Summary

Coordinated, focused limited duration (FY82-FY90) major thrust

Spike Fund Pacing R&D

Major University Involvement

Encourage Coalitions

Planned Technology Insertion

Timely Transition of Leadership to Industry Organization

AEROSPACE INDUSTRIAL MODERNIZATION AND THE INDUSTRY/DEPOT ROBOTICS SURVEY

WRIGHT-PATTERSON AFB
AFSC/PMI

BY: F.C. BROOKS

The Aerospace Industrial Modernization (AIM) Office (AFSC/PMI) has been tasked to conduct a robotics technology assessment and prepare an implementation plan. The robotics assessment will be conducted through a two-phased contractual effort. In the first phase the current state-of-the-art of robotics technology will be determined as a function of efforts within Government, industry, academic and private institutes, and selected foreign countries. These findings will serve as a basis to predict mature robotics technologies for FY85 through FY89. In the second phase of the assessment, the state of robotics implementation in the aerospace industry, and prioritized opportunities for robotics implementation will be determined. The results of the assessment will be used for preparation of a plan to accelerate robotics implementation in the aerospace community.

PHASE I INFORMATION SOURCES

GENERAL	AF LABS	AF SYSTEMS ORGS
AFOSR	AEDC	AD
	AFFTC	AFCMD
DARPA	AFGL	AFLC/XRP (2)
	AFHRL	ASD
DARCOM	AFIT/ENG	BMO
	AFWAL	ESD
EOARD	AA	SD
	FI	
		AF OPERATING COMMAND
NASA HQ	ML	
	PO	MAC
ONR	AFWL	SAC
	AMD	
DEPT COMMERSE	FTD	
BUREAU STDS	SAMTO	

PHASE II INFORMATION SOURCES

AEROSPACE CONTRACTORS	AIR FORCE LOGISTICS	AIR FORCE OPERATIONAL
AD	AFLC	MAC
AFCMD	OC-ALC	SAC
ASD	OO-ALC	TAC
ESD	SA-ALC	
SD	SM-ALC	
	WR-ALC	

FUTURE ROBOTICS PROGRAM AT SAN ANTONIO ALC

-SAN ANTONIO AIR LOGISTICS CENTER/RESOURCES MANAGEMENT DIVISION
SA-ALC/MAW

BY: DOUG FERRY

INTRODUCTION:

Good Afternoon, ladies and gentlemen. I'm Doug Ferry from the San Antonio Air Logistics Center at Kelly AFB, Texas.

Today I would like to discuss the future maintenance robotics program for Kelly. As you heard earlier from Mr Lee we presently have one on-going robotic project in the engine repair facility (the Plasma Spray Process). An additional automated paint processing cell is under contract, to be operational by June 1984.

In 1982 the Southwest Research Institute (SWRI) in San Antonio, Texas was contracted to study and analyze the feasibility of modernizing the maintenance shops at Kelly. The study was completed in June 1983. A comprehensive design and analysis of our maintenance depot operations was performed, with emphasis on potential robotics and automated applications to achieve modernization. The SWRI staff spent over 400 hours on shop floors observing operations in jet engine and airframe inspection, overhaul and repair. All primary processes were considered: Disassembly, cleaning, inspection, machining, heat treating, welding, coating, assembly and painting. Thirty five separate work areas in maintenance were surveyed. Interviews were conducted with maintenance workers, supervisors, engineers and support personnel. On-site inquiries were made to manufacturers such as GE, Cincinnati Milacron, Graco, and PRAB. SWRI also consulted with USAF Integrated Computer Aided Manufacturing (ICAM) office, SA-ALC members and SWRI process specialists to ensure a completed product was presented.

While many possible projects are addressed, the main thrust of a 1982 ~~the SWRI~~ study is the identification of six candidates for best application of robotic and automation. These six were then designed, cost estimated, and analyzed for cost/benefit and return on investment for possible future implementation. They are:

Robotic Machine Vision Inspection Station,
Robotic Material Handling System,
Robotic Deriveting System,
Robotic Welding Station,
Robotic Rework Station, and
Robotic Inspection Station (F100 Flame Holder).

We should note that two of these projects involve inspection and would use similar hardware. Two involve welding and repair projects with similar system design.

I will now, very briefly, summarize each of the six robotics projects presented for possible implementation. Of necessity the descriptions of the projects and equipment will be very general.

ROBOTIC/MACHINE VISION INSPECTION STATION

The dye penetrant and white light inspection process of large jet engine parts using a robot and robot vision was seen by SWRI to be a very promising potential application area. Initially, the robotics station will be restricted to the F100 engine augmentor module parts. The system consists of a robot adapted with a vision system and a high speed computer to process image patterns. In addition the inspection process will produce a computerized historical data base for each part inspected. Cost is estimated at $565,000. Projected savings of $145,000 annually would give a four year payback period. Greater accuracy, less rework and relief of labor intensity will result from successful completion of this project.

ROBOTIC MATERIAL HANDLING SYSTEM

This system was recommended to enhance the existing engine repair facility's automated cleaning system. It basically will sort and load small baskets of jet engine parts into large baskets, prior to chemical cleaning. The system is designated with two robots. A robot testing terminal, a microcomputer and basket loading pallets. Total cost is estimated at $356,000; savings at $135,000 annually; and a payback of less than three years. Relief of manual labor, safety improvement, increased use of existing equipment, and less congestion on shop floors will be possible upon implementation.

ROBOTIC DERIVETING SYSTEM

The B-52 parts rework procedure requires the manual removal of numerous rivets and fasteners from a variety of sheet metal parts. In some instances, as many as 1000 rivets per part are removed. It is necessary to remove these rivets and fasteners from the parts so their interiors may be exposed for inspection and periodic repair. An example of such gross access is the B-52 wing flap. The labor required is highly-skilled and labor intensive. The task is monotonous and repetitive. Damage to the part is frequent because of accidental drilling and punching. The worker must position himself on instable surfaces (ladders, stools), and in awkward and uncomfortable positions on the floor. Use of the proposed automatic robotic deriveter system would believe these indesirable characteristics of the present process. Consisting of a robot, deriveter end-effector and computer control, the system is estimated to

cost $1,250,000. Savings could amount to $350,000 annually. Payback would be under four years.

SWRI is working a contract for the Navy, at the present time, to develop a deriveting system. We fully expect to benefit, economically and technologically, from these efforts.

ROBOTIC WELDING STATION

A robotic welding station has been designed and recommended for our engine repair facility. There are sufficient engine parts that require and receive repetitive and predictable welds. This system would supplement and enhance the Dabber I, a semi-automated, processor controlled GIAW welding machine, currently in use at Kelly. The system would include a small industrial robot, a workpiece welding positioner, welding equipment including a programmable seam tracker. This station is designed for low risk and fast payback. Total cost is estimated at $154,800; savings at $15,451 monthly; payback time in less than a year. The station will produce superior and consistent welds, less rework, shorter turnaround, and lessen the welding work load on other welders and equipment.

ROBOTIC REWORK STATION

A robotic rework station has been recommended for and designed primarily around the needs of the TF39 compressor rear frame, the pacing item in the overhaul of the TF39 jet engine, which powers the C5 Galaxy Aircraft. However, it will be equally applicable to other jet engine parts. The rework station is designed to perform fight rework processes--metal scalloping, blending, drilling, reaming, counterproofing, burnishing, GTA welding and weld build-up. The station uses the concept of "clustering" where parts are brought to a cluster of equipment and processes. It should be emphasized that this is an advanced complex robot system application involving high skill operations. The proposed equipment represents the state of the art in industrial robots, robotic controls, workpiece, positioners, welding technology, and end-effectors. Estimated cost of the station is $295,000; savings $25,000 monthly; giving a payback period of twelve months. Substantial flowdays reduction and reduced parts turnaround would be realized.

ROBOTIC INSPECTION STATION (F100 FLAME HOLDER)

The sixth robotic project recommended for best application is an inspection station for F100 Flame Holders. This system consists of a hydraulic robot, vision system, computer, advanced applications software and miscellaneous hardware. Automated Inspection is a technology which can pay for itself, although, in the long run it is seen as only the first step in the total automation of Flame Holder rework, to be followed later by welding and grinding. The estimated cost of the projects is $290,000. The estimated

$16,000 monthly savings would provide a payback time of approximately eighteen months.

As you can see, the processes recommended are for high production and difficult to repair components. Implementation of any of these projects would represent an ambitious program for any activity. We intend to pursue these six projects along with others during FY84 through 86 timeframe, as potential initiatives in the productivity, reliability, availability, maintainability program or more commonly known as the PRAM program. (PRAM).

CONCLUSION:

We are confident that the application of robotics and automation technologies will greatly enhance our productivity, improve the working environment and increase our overall production. Achieving these alone would make our efforts worthwhile. But these projects are not intended to reap benefits just for the San Antonio Air Logistics Center. Our projects are also being introduced for the advancement of technology. The intent is to gain the knowledge and expertise required to implement similar applications in other production settings. Having gained this knowledge and expertise, we can then share them with you, as we hope you will share your gains with us. Thank you.

ROBOTICS IN NONDESTRUCTIVE INSPECTION AT SACRAMENTO AIR LOGISTICS CENTER

SACRAMENTO AIR LOGISTICS CENTER
SM-ALC/MANE

BY: DOUG FROOM

ON-AIRCRAFT MANEUVERABLE REAL TIME X-RAY INSPECTION SYSTEM

This system shall provide for the inspection of bonded components on the aircraft through high quality, real time microfocus x-ray imaging. This capability will eliminate the necessity of routinely removing component structures from the aircraft for the purpose of x-ray inspection. Only those parts which are shown to be detective need to be removed from the aircraft for repairs, thereby dramatically reducing the time required for the aircraft overhaul. The system will be capable of performing both film and filmless x-ray imaging and provide high quality archival inspection records.

The Maneuverable Real Time X-Ray Inspection System will be installed in a dedicated Nondestructive Inspection (NDI) facility. The system will primarily inspect the F-111 and FB-111 aircraft but will have a general applicability to any aircraft that will fit within the inspection envelope of 76'11" l x 72'4" w x 18' h. Other aircraft known to be inspected are the F-105, F-106, F-4 and A-10 fighter aircraft.

The Maneuverable Real-Time X-Ray Imaging System will be suitable for foreign object detection in fuel cells, wet wings and other enclosed spaces. Foreign object detection is limited only by: 1) accessibility of the area to be inspected, 2) the ability of the x-ray beam to penetrate the area to be inspected, and 3) the detectability of the detectability of the foreign object itself.

The Maneuverable Real Time X-Ray Inspection System is comprised of three major components:

1. Robotic Overhead Positioning System (ROPS)
2. X-Ray Real Time Imaging System
3. Operations Control Room

The positioning and imaging system will be housed in a dedicated radiation-shielded x-ray inspection hangar bay, designed to accept the Maneuverable Real Time X-Ray Inspection System.

This specified system is intended for use in an aircraft inspection and repair environment to detect mechanical deficiencies in conventional and bonded honeycomb panel assemblies. The system will provide for a permanent record of the x-ray inspection findings along with identification of the part and inspection site coordinates through the use of video hard copies and in-motion recordings for subsequent repair implementation and part dispositioning. The imaging system must be designed to operate in a radiation shielded room approximately 92' 11" L by 85' 6" W x 45 ft H. The operator's control console will be designed to fit into a 18 ft W x 20 ft L air conditioned operator's control booth that will permit the operator to see the airplane through a shielded window.

The real time x-ray imaging system will be designed to provide a complete real time x-ray imaging capability.

The robotic overhead positioning system will position the x-ray source and imager accurately to provide an automatic scan of the required aircraft areas. A bridge and trolley will position in the X and Y axes (horizontal axes to the bay floor) and a telescoping mast will provide travel in the Z axis (vertical). A yoke assembly with at least three (3) degrees of freedom will be attached to the telescoping mast and position the x-ray source and imager on opposite sides of the test areas on the aircraft. The system will provide computer control to:

1. Locate the airplane and specific section of the aircraft for inspection.

2. Position the x-ray source and imaging system for the inspection.

3. Automatically scan the selected component.

4. Be able to interrupt the automatic scan and be receptive to manual control to provide a more detailed microfocus x-ray magnified view to enhance interpretation.

5. Automatically move to scan the next programmed component.

6. Provide for recording and recall of x-ray inspection information by component.

7. Provide flaw location information relative to the component under test.

8. Permit the application of selected image enhancement procedures including:

   a. Frame averaging to minimize noise in moving images.

   b. Frame summing to enhance contrast.

c. Edge enhancement.
d. Image subtraction.
e. Video polarity reversed.

The real time x-ray inspection will employ a 160KV high output microfocus constant potential industrial x-ray source and a conventional 320KV constant potential industrial x-ray source for heavier sections. Either source may be remotely selected and used in conjunction with an x-ray image intensifier system. High resolution closed circuit TV displays will be utilized to display at the operator's console to: 1) view high quality real time x-ray images of the test, 2) monitor as-recorded real time x-ray images, 3) view visual images from TV cameras in the inspection bay, and 4) review selected recorded images of prior radiographic examinations for comparison.

Mechanical movement of the x-ray inspection system will be by a robotic overhead positioning system that will move under computer control to provide smooth, chatter-free movement with 6 degrees of freedom. Repositioning accuracy for the mechanical system will be $\pm 1/2$ inch.

The operator will activate the inspection system by calling for the inspection of a particular section of the aircraft (for example, the left wing). The scan plan will have been programmed into the system computer previously. The automatic inspection scan will begin on the selected component such as the leading edge section of the wing. The particular component will then be scanned in a preprogrammed manner.

The operator will observe the real time x-ray image on the high resolution TV monitor and record the results on video tape. The purposes of the x-ray inspection are to detect defective bonded components in terms of impact damage, deteriorated core, water, corrosion or debonds. Once a component has been identified as defective, it must be removed for detailed inspection and repair; there is no need to proceed with the inspection of a component already identified for removal. The operator may wish to compare the current inspection results with results obtained in previous x-ray or neutron inspections. Therefore, provisions have been made to permit viewing of taped records of previous inspections. These will be available for recall by component/part number.

If the inspection of the particular component discloses no defective areas, the system will be directed to the next component. If the operator detects a suspect area, he will have provision to interrupt the automated scan for manual operation to stop in place, change the radiation angle, magnify the image geometrically using the microfocus focal spot, or use image enhancement. If the decision is made that the particular component is defective, the operator can initiate an ink marking system to mark the defective part for removal. The automated inspection process would then resume.

The operator will be able to observe the aircraft through a radiation-shielded window in the operator's control room. The operator will also be able to observe the aircraft by closed circuit TV (CCTV) displayed on monitors in the control console. Anti-collision devices will prevent collision of the maneuverable system with the aircraft. These anti-collision devices will be effective both in the automatic scan and manual control mode.

The positioning system will be designed to provide smooth, chatter-free movement for the x-ray inspection equipment. The bridge and carriage will carry the weight of the vertical, telescoping mast, the yoke assembly and the complete x-ray inspection equipment including x-ray tubeheads, high tension power supplies, coolers, pumps, cables and imaging equipment which will be mounted atop the positioner carriage. Cables must be controlled in a festooning system so that they move in a jerk-free, smooth manner and do not interfere with the movement of the system or catch on aircraft components. The system will have a repeatability in each the X and Y axes of ± 1/4 inch.

ON-AIRCRAFT MANEUVERABLE NEUTRON RADIOGRAPHY INSPECTION SYSTEM

This system shall provide for the inspection of bonded components on the aircraft through high quality near real time neutron ray (N-ray) imaging. This capability will eliminate the necessity of routinely removing component from the aircraft for the purpose of N-ray inspection. Only those parts which are shown to be defective need to be removed from the aircraft for repairs, thereby dramatically reducing the time required for the aircraft overhaul. The system will be capable of performing both film and filmless N-ray imaging and provide high quality archival inspection records. It shall provide both an overhead mounted system and a ground-based system in order to inspect all required areas of the aircraft.

The Maneuverable Neutron Radiography Inspection System will be installed in a dedicated Nondestructive Inspection (NDI) facility. The system will primarily inspect the F-111 aircraft but will have a general applicability to any aircraft that will fit within the inspection envelope of 76' 11" L X 73' W X 18' H. Other aircraft known to be inspected are the F-105, F-4 and A-10 fighter aircraft.

The Manueverable Neutron Radiography Inspection System is comprised of the following major components:

1. Robotic Overhead Positioning System (ROPS).

2. Overhead Near Real Time Neutron Radiography Imaging System.

3. Ground-based Neutron Radiography System.

4. Operations Control Room.

The positioning and imaging system will be housed in a dedicated radiation-shielded N-ray inspection hangar bay (provided by others) and designed to accept the Maneuverable Neutron Radiography Inspection System.

This specified system is intended for use in an aircraft inspection and repair environment to detect corrosion of aluminum honeycomb. The presence of internal corrosion indicates existence of a moisture entry path which would lead to rapid deterioration if returned to service without rework.

The system will provide near real time (filmless) neutron inspection coverage for on-aircraft inspection of honeycomb components in the F-111, primarily, and similar coverage for selected components of the F-4, F-105, F-106 and A-10 aircraft. The Maneuverable Neutron Radiography System will consist of two radiography systems. One will be an overhead gantry positioning system and the other will be a ground-based positioning system. The overhead system is for the inspection of wings, vertical and horizontal stabilizers, and any area reachable where near real time imaging is required. The ground-based system is needed for film radiographic inspection of the engine bays and accessible fuselage areas. Each system will utilize 50 milligrams of California -252 as a source of neutrons with a Moderator Collimator Shield (MCS) assembly that will provide a collimated beam of thermal neutrons. This source material will be supplied by the U.S. Department of Energy, however both systems will be designed to accept encapsulated Calitornium.

Mechanical movement of the N-ray inspection system will be by a robotic overhead positioning system that will move under computer control to provide smooth, chatter-free movement with 6 degrees of freedom. Repeatability for the mechanical system must be $\pm$ 1/2 inch.

The robotic overhead positioning system will position the N-ray source and imager accurately to provide an automatic scan of the required aircraft areas. A bridge and trolley will position in the X and Y axes (horizontal axes to the bay floor) and a telescoping mast will provide travel in the Z axis (vertical). A yoke assembly with at least three (3) degrees of freedom will be attached to the telescoping mast and position the N-ray source and imager on opposite sides of the test areas on the aircraft. The system will provide computer control to:

1. Locate the airplane and specific section of the aircraft for inspection.

2. Position the N-ray source and imaging system for the inspection.

3. Automatically scan the selected component.

4. Be able to interrupt the automatic scan and be receptive to manual control to provide a more detailed N-ray view to enhance interpretation.

5. Automatically move to scan the next programmed component.

6. Provide for recording and recall of N-ray inspection information by component.

7. Provide flaw location information relative to the component under test.

The aircraft is positioned in the hangar tail first with the nose and main gear wheels positioned to an accuracy of $\pm$ 4 inches. The aircraft will remain on the ground (jacking is not necessary) and is leveled fore to aft and port to starboard by adjusting the gas pressure in the nose and main landing gear struts. The robotic overhead positioning system will, through its software, adjust its frame of reference to the actual position and trim of the aircraft when the inspection process begins.

The operator will activate the inspection system by calling for the inspection of a particular section of the aircraft (for example, the left wing). The scan plan will have been programmed into the system computer previously. The automatic inspection scan will begin on the selected component such as the leading edge section of the wing. The particular component will then be scanned in a preprogrammed manner.

If the inspection of the particular component discloses no defective areas, the system will be directed to the next component. If the operator detects a suspect area, he will have provision to interrupt the automated scan for manual operation to stop in place, change the radiation angle, or use image enhancement. If the decision is made that the particular component is defective, the operator can initiate an ink marking system to mark the defective part for removal. The automated inspection process would then resume.

The operator will be able to observe the aircraft through a radiation-shielded window in the operator's control room. The operator will also be able to observe the aircrft by CCTV's displayed on monitors in the control console. Anti-collision devices will prevent collision of the maneuverable system with the aircraft. These anti-collision devices will be effective both in the automatic scan and manual control mode.

NAVAL AIR DEPOT FUTURE ROBOTICS/AUTOMATION PROJECTS

NAVAL AVIATION LOGISTICS CENTER
BY: RONALD WIMMER

ROBOTIC AIRCRAFT STRIPPING

.. OBJECTIVE	TO MORE EFFICIENTLY REMOVE PAINT FROM AIRCRAFT SURFACES WHICH ARE EASILY DAMAGED.
.. PROPOSED METHOD:	TO UTILIZE ROBOTICS IN CONJUNCTION WITH APPROPRIATE PROCESSES TO SOFTEN AND REMOVE AIRCRAFT PAINT EFFICIENTLY WITHOUT HARM TO COMPOSITES, ELASTOMERS, METALS, OR ANY COMPONENT.
.. PROJECTED COST:	$4,500,000
.. PROJECTED SAVINGS:	$1,450,000/YR
.. PAYBACK PERIOD:	3.1 YRS
.. KEY PLANNING FACTORS:	- REDUCED LABOR - IMPROVED QUALITY - IMPROVED TURN-AROUND TIME

ROBOTIC TURBINE VANE REMOVAL

.. OBJECTIVE	TO UTILIZE A MORE COST EFFECTIVE ALTERNATIVE TO THE PRESENT LABOR INTENSIVE METHODS OF GRINDING OUT VANES IN THE J-79 ENGINE.
.. PROPOSED METHOD:	ADAPT ROBOTIC GRINDING GUIDED BY THE NON-UNIFORM VANES INTERIOR SURFACES OR PREFERABLY UTILIZING A CUTTING LASER WITH A ROBOTIC VISUAL GUIDANCE SYSTEM PICKING UP THE INTERIOR CONFIGURATION OF THE VANES.
.. PROJECTED COST:	$1,800,000
.. PROJECTED SAVINGS	$555,000/YR
.. PAYBACK PERIOD	3.2 YRS
.. KEY PLANNING FACTORS:	- WORKLOAD PROJECTIONS FOR J-79's - LARGF LABOR REDUCTIONS

ROBOTIC SMALL PARTS PAINTING

.. OBJECTIVE: TO PROVIDE FLEXIBLE MEANS FOR APPLICATION OF PAINT TO A WIDE VARIETY OF AIRCRAFT PARTS.

.. PROPOSED METHOD: TO UTILIZE ROBOTIC VISION SYSTEMS TO DIRECT A DISCRETE NUMBER OF PAINT SPRAY PATTERNS TO PAINT A RANDOM SEQUENCE OF VARIOUS SIZES AND SHAPES OF PARTS SUSPENDED FROM A CONVEYOR.

.. PROJECTED COST: $525,000

.. PROJECTED SAVINGS: $245,000/YR

.. PAYBACK PERIOD: 2.1 YRS

.. KEY PLANNING FACTORS:
- CENTRALIZE ALL SMALL PARTS PAINTING
- REDUCE LABOR

ROBOTIC

ABRASIVE COMPONENT PAINT & CORROSION REMOVAL

.. OBJECTIVE:	TO AUTOMATE THE REMOVAL OF PAINT AND CORROSION FROM VARIOUS A/C PARTS PRIOR TO REWORK
.. PROPOSED METHOD:	TO UTILIZE PRE-PROGRAMMED COMPUTER CONTROLLED EQUIPMENT TO OPTIMIZE THE REMOVAL OF PAINT AND CORROSION VIA A SELECTED BLASTING MEDIUM
.. PROJECTED COST:	$560,000
.. PROJECTED SAVINGS:	$267,000
.. PAYBACK PERIOD:	2.1 YRS
.. KEY PLANNING FACTORS:	- REDUCE LABOR OF 22 FULL TIME PERSONNEL BY 10% - DECREASED RISKS

ROBOTIC AIRCRAFT CANOPY POLISHING

.. OBJECTIVE:	TO PROVIDE FLEXIBLE MEANS FOR POLISHING A VARIETY OF AIRCRAFT CANOPIES TO HIGH VISUAL CLARITY.
.. PROPOSED METHOD:	UTILIZE A ROBOT IN LIEU OF PRESENT HAND OPERATIONS WITH AN APPROPRIATE SET OF VISUAL SYSTEMS - TO LOCATE THE CANOPY SURFACES AND TO REMOVE OPTICAL DEFECTS WITH OPTIMUM EFFICIENCY.
.. PROJECTED COST:	$400,000
.. PROJECTED SAVINGS:	$152,000/YEAR
.. PAYBACK PERIOD:	2.6 YRS
.. KEY PLANNING FACTORS:	- APPLIES TO ALL KNOWN AIRCRAFT - LABOR SAVINGS - QUALITY IMPROVEMENT - MAY BE FIELD ADAPTABLE

COMBUSTION CHAMBER REWORK PROCESSING SYSTEM

PROBLEM: IN THE TYPICAL REWORK OF COMBUSTION CHAMBERS, SIX DIFFERENT SHOPS PERFORM 44 OPERATIONS INCLUDING CUTTING THE DOMES OFF, HAND BLASTING CHAMBER INTERIOR AND REATTACHING THE DOME BY WELDING. INHERENT PROBLEMS INCLUDE CLOSE TOLERANCES AND LARGE AMOUNT OF GRINDING.

PROPOSED SOLUTION: ESTABLISH A GROUP TECHNOLOGY CELL TO INCLUDE LASER CUTTER/WELDER AND ROBOTIC SYSTEMS FOR WELDING, GRINDING, AND WORK POSITIONING.

TOXIC MATERIALS MACHINING CENTER

PROBLEM: MACHINING AND/OR GRINDING OF SOME AIRCRAFT PARTS PRODUCES FINE PARTICLES WHICH ARE POTENTIALLY TOXIC. THESE PARTICLES CONSIST OF NICKLE,.GRAPHITE AND BERYLLIUM ALLOYS.

PROPOSED SOLUTION: THE HANDLING AND MOVING OF THESE PARTS INTO AND ABOUT A FLEXIBLE MACHINING CENTER ARE POTENTIAL USES OF ROBOTIC MACHINERY. OPERATORS COULD BE REMOVED FROM THE POTENTIAL HAZARD CREATED IN THESE OPERATIONS.

FINAL INSPECTION OF MISSILES

PROBLEM: CURRENTLY FINAL INSPECTION OF MISSILES IS A REPETITIOUS AND ERROR PRONE PROCESS. ERRORS RESULT IN INCREASED COSTS AND LOWER FLEET WEAPON SYSTEM READINESS.

PROPOSED SOLUTION: A TELEVISION INSPECTION SYSTEM COUPLED WITH A MISSILE POSITIONING/CONTROL SYSTEM CAN INSPECT A MISSILE AUTOMATICALLY. THE SYSTEM WOULD STORE ALL ACCEPTANCE CRITERIA. THE CAMERA SYSTEM WOULD VIEW THE MISSILE AND COMPARE IT AGAINST THE STORED ACCEPTANCE CRITERIA.

SMALL PARTS CLEANING

PROBLEM: MANY PARTS THAT INVOLVE PAINT STRIPPING ARE HOLLOW (SUCH AS AIRCRAFT DOORS) OR HAVE MATERIALS OR MACHINED SURFACES (SUCH AS MISSILE FINS) THAT WOULD BE DAMAGED IF CLEANED BY DIPPING IN A CHEMICAL TANK. THESE PARTS ARE PRESENTLY DONE BY HAND AT A GREAT TIME EXPENSE.

PROPOSED SOLUTION: PROGRAM A ROBOT TO ACCEPT THESE REPETITIVE PARTS, APPLY PAINT STRIPPER TO THE DESIRED SURFACES, SCRUB THE SURFACE WITH A ROTATING BRUSH AND RINSE THE PART WITH A DETERGENT SOLUTION.

AIRFRAME COMPONENTS INSPECTION

PROBLEM: CURRENT NON-DESTRUCTIVE INSPECTION OF AIRFRAME COMPONENTS IS VERY LABOR INTENSIVE.

PROPOSED SOLUTION: DEVELOP A ROBOTIC FIXTURE DEVICE THAT WOULD ROTATE THE LARGE COMPONENT THROUGH THE REAL TIME X-RADIOGRAPHY PROCESS AND AUTOMATICALLY MARK ANY DEFECTS.

POTENTIAL APPLICATIONS

- INSPECTION OF BALL BEARINGS - ROBOTIC VISION SYSTEM TO SORT FOR SIZE, AND TYPE AND CHECK SMOOTHNESS.
- INSERTION OF MISSILE COMPONENTS - ROBOTIC MANIPULATION/VISION SYSTEM TO ENABLE REPLACEMENT OF STATIC SENSITIVE AND MECHANICALLY FRAGILE COMPONENTS.
- ROBOTIC VISUAL PARTS SORTING - UTILIZE ROBOTIC VISION SYSTEMS TO RAPIDLY IDENTIFY AND SORT ALL TYPES OF AIRCRAFT FASTENERS AND SMALL COMPONENTS.
- COMPUTER CONTROLLED FLUORESCENT PENETRANT LINE - AN AUTOMATED AND INTEGRATED SYSTEM FOR NDI OF ENGINE COMPONENTS USING ROBOTIC SYSTEMS FOR ELECTRO-STATIC SPRAY APPLICATION OF PENETRANT, RINSING AND DEVELOPING AND PARTS REPLACEMENT.
- HELICOPTER ROTOR BLADE PAINTING - UTILIZE ROBOTIC SYSTEMS FOR BOTH APPLYING PAINT TO BLADES AND LOADING, UNLOADING AND POSITIONING BLADES FOR PAINTING.
- METAL SPRAY COATING - ROBOTIC SYSTEMS FOR APPLYING VARIOUS METAL SPRAY COATINGS ONTO COMPONENTS AND FOR LOADING, UNLOADING AND POSITIONING COMPONENTS FOR SPRAYING.
- ROBOTIC DRILL AND ROUT CELL - ROBOTIC SYSTEMS TO DRILL AND CONTOUR CUT COMPLEX AIRCRAFT PARTS.

SHIPYARD AUTOMATION, ROBOTICS APPLICATIONS AND PLANS

NAVAL SEA SYSTEMS COMMAND

BY: ROY WELLS

DOD ROBOTIC WORKSHOP OUTLINE

PROPELLER MANUFACTURING CENTER OF THE
PHILADELPHIA NAVAL SHIPYARD

The Propeller Manufacturing Center of the Philadelphia Naval Shipyard is responsible for the entire production process for the manufacture of submarine propellers. This includes the pattern development, propeller molding and casting, bulk metal removal by NC methods, and the manual final finishing measuring, and certification of the propeller. Currently propeller design data is computer processed to assist in the pattern development, gage manufacture, and the certification process; ~~while~~ the NC function is entirely computerized. Still the basic manufacturing processes are performed manually. For example, the final required grinding, welding, and polishing are left to the artistic abilities of the shop personnel. Furthermore, the dimensional inspection of a finished propeller is a tedious and extremely labor intensive manual process which is accomplished by the application of sheet metal gages made to the contour of the blade cross sections. This method offers the potential for misreading or misinterpreting many of the appproximately 500 measurements made on each blade. In recognizing these problems as well as the trend toward more sophisticated propeller designs, the associated need for greater manufacturing accuracy to meet stringent performance requirements, the dramatically increasing labor costs, and the depletion of qualified and experienced machinists, NAVSEA, and the Propeller Manufacturing Center were prompted to undertake a program to modernize propeller manufacturing techniques.

As a result, a total concept of an automated manufacturing process was devised, robotic technology was investigated, and the development and fabrication of these new systems are currently underway. Specifically, PNSY Propeller Manufacturing Center has contracted for four major robotic systems: APOMS (Automated Propeller Optical Measurement System), PAWS (Propeller [illegible] Welding System),

cont

PRATS (Propeller Robotic Automated Templating System), and PROFS (Propeller Robotic Optical Finishing System). Viewgraphs ...

PRATS, and PROFS. Viewgraphs will show the actual or conceptual design including the ultimate Integrated Computer Aided Manufacturing Propeller System (ICAMPS), a multi-work station for processing four propellers simultaneously.

APOMS (AUTOMATED PROPELLER OPTICAL MEASUREMENT SYSTEM)

MAJOR FEATURES

--consists of 3 axis (x,y,z) positioner assembly including a boom structure which supports the measuring device.

--the measuring device is a 3-D optical scanning mechanism with 2 axis (pitch, roll) flexibility

--measuring device maintains a distance of 35" from subject

--total structure is 26' high resting on a foundation 6' below floor level

--z-axis boom structure will be mounted on a turntable for APOMS access to all 4 pits

--60 ft^2/hr measuring rate; ±0.025 measurement accuracy; error between any 2 points within 6 inches of one another not to exceed ±0.001 inches

--APOMS collects much more data than conventional means in half the time

--expected to reduce by multi thousand manhours/year the manhours required to measure propellers

COMPUTER HARDWARE HIGHLIGHTS

--operates in real time

--driven by HP1000F mini-computer with 1.5 Mb memory

--120 Mb disk drive capable of storing 1 completely measured propeller (40 Mb)

--tape drive for off-line storage

--electronics cabinet contains integrated circuits to track axial position of APOMS unit and preprocess the data from the optical sensor.

SOFTWARE HIGHLIGHTS

--RATFOR - FORTRAN variation

--collision avoidance

--selectable scan rates and paths

--generates final inspection report by comparing measured propeller data to design data

PRATS (PROPELLER ROBOTIC AUTOMATED TEMPLATING SYSTEM)

MAJOR FEATURES

--6 axis industrial robot with detachable drill or templating assembly

--mounted on slideways (rails) for access to propeller extremities

--drills spherical holes with a ball end mill

--holes are drilled perpendicular to APOMS measured surface to final finish depth

--final finish depth determined from the excess material map generated by comparing measured propeller to design

--templating used to guide hand grinding or PROFS operation

--conventional technique involves hand grinding, measuring, hand grinding, measuring etc. (an iterative process) until desired contour is achieved

COMPUTER HARDWARE

--driven by HP1000F mini-computer (separate from APOMS computer)

--tape and disk drive similar to APOMS

SOFTWARE

--selectable templating density

--RATFOR

--best fits the measured propeller to the design before generating the excess material map

--best fit means minimizing excess material on pressure face

PAWS (PROPELLER AUTOMATED WELDING SYSTEM)

--6 axis industrial robot with detachable welding fixture

--minimize heat related distortions

--60% time savings in clad welding

--driven by Motorola 68000 microcomputer

--FORTRAN, ASSEMBLY Language software stored in ROM

PROFS (PROPELLER ROBOTIC OPTICAL FINISHING SYSTEM)

--6 axis industrial robot with detachable grinding tool assembly

--mounted on slideways (rails) for access to propeller extremities

--utilizes optical sensing mechanism

--grinding is terminated when the vision system senses the disappearance of the templated holes or peripheral grooves

--designed to grind approximately 0.050 inches of excess material

GENERAL ROBOT

--Cincinnati MILACRON HT3

--6 axis (base sweep, shoulder swivel, elbow extension, pitch, yaw, roll)

--5' floor to pivot; 8' reach from pivot

--same Robot can be used for PAWS, PRATS, or PROFS

--conversion process can be accomplished within one hour

NAVAL SEA SYSTEMS COMMAND ROBOTICS PROGRAM

BY: LCDR BART EVERETT

NAVSEA Robotics Coordination Activity

- **Goal:** To Provide for the Timely Introduction of Robotics Technology and Systems Into Naval Sea Systems Manufacturing, Construction, Maintenance, Repair, and Operations.

- **Approach:** Develop an Integrated NAVSEA Robotics Program Through an Informal Council Coordinating all NAVSEA Robotics Applications Analyses, Technology Development, Systems Tests and Demonstrations, Data Aggregation and Dissemination, and Implementation.

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NAVSEA Manufacturing Technology Program

- CNC/Robotic Structural Shape Processing System
- Integrated Computer Aided Manufacturing of Propellers
- Articulating Robotics for Laser-Assisted Metal Working
- Vision Assisted Robotics Welding
- Vision Assisted Adaptive MIG Welding
- Robotics Assisted Surface Preparation and Painting

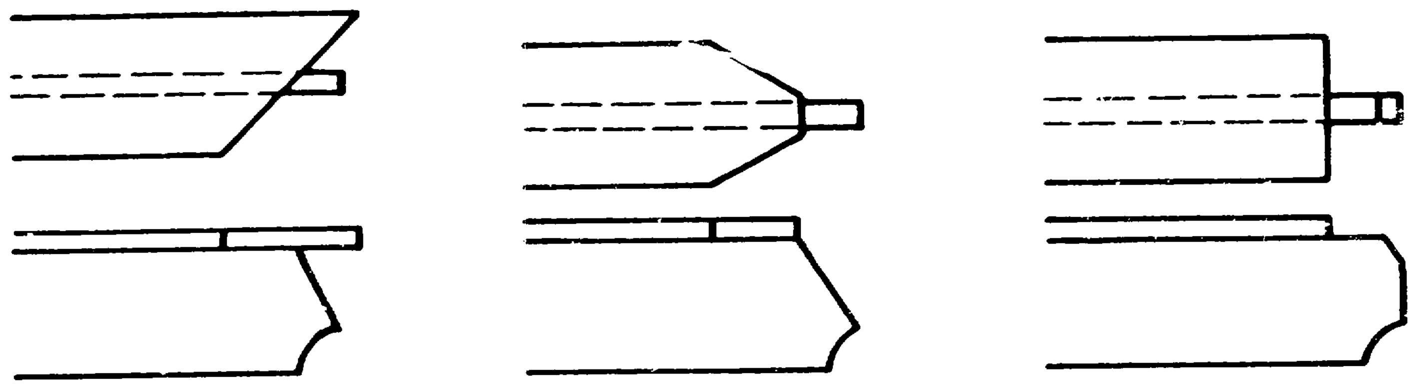
CNC/ROBOTIC STRUCTURAL SHAPE PROCESSING SYSTEM

- PROJECT DESCRIPTION: DEVELOP A SYSTEM FOR FABRICATING STEEL AND ALUMINUM STRUCTURAL SHAPES COMMONLY USED IN SHIPBUILDING.
  - PHASE 1: SPECIFICATION DEVELOPMENT AND FEASIBILITY DEMONSTRATION
  - PHASE 2: INSTALLATION AND TECHNOLOGY TRANSFER DEMONSTRATION
- CONTRACT FOR PHASE 1 WAS AWARDED 31 DECEMBER 1981 TO BATH IRON WORKS WITH AUTOMATIX, INC AS SUBCONTRACTOR.
- PHASE 2 ANTICIPATED TO BEGIN LATE 1983

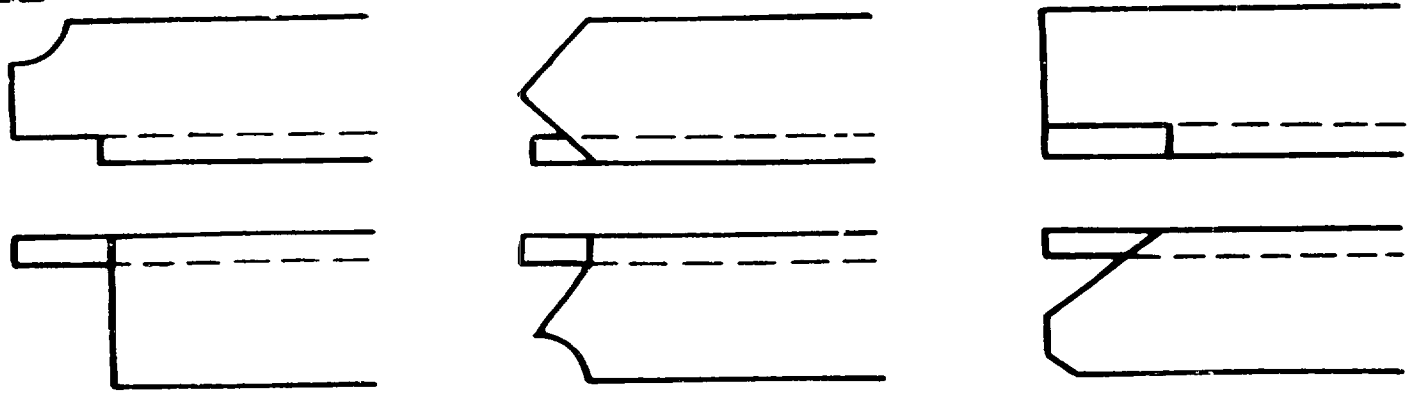
PROJECT MANAGER: BOB JENKINS
DTNSRDC CODE 1853
(202) 227-1363

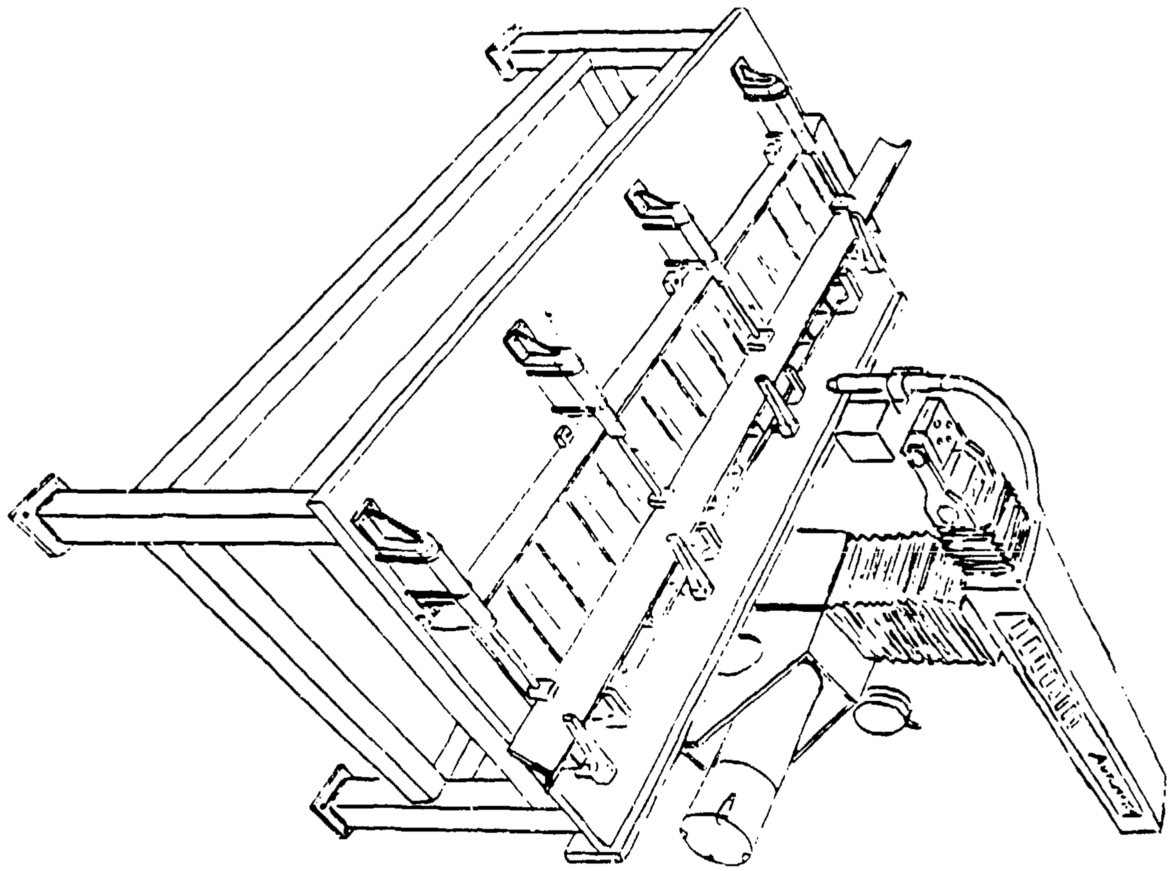
SAMPLE STRUCTURAL END CUTS

T-BARS



ANGLE





GENERAL DESCRIPTION

- WILL INCORPORATE
  - COMPUTER AIDED DESIGN AND PARTS PROGRAMMING
  - CNC/ROBOTIC CUTTING AND MARKING
  - SEMI-AUTOMATIC MATERIAL HANDLING
- WILL INCLUDE TWO MAJOR SUBSYSTEMS
  - NUMERICAL CONTROL SUPPORT SYSTEM (NCSS)
  - ROBOTIC PROCESSING CENTER (RPC)

NUMERICAL CONTROL SUPPORT SYSTEM

- PROVIDE SOFTWARE TO EXTRACT DATA FROM EXISTING CAD/CAM SYSTEM
- PROVIDE POST-PROCESSING TO DEVELOP COMMANDS FOR OPERATION OF THE ROBOTIC PROCESSING CENTER
- CAPABILITIES WILL INCLUDE:
  - PARTS PROGRAMMING
  - NESTING OF PARTS
  - GENERATION OF RAW MATERIAL LOADING LIST
  - VARIOUS PRODUCTION DOCUMENTATION

ROBOTIC PROCESSING CENTER

- PERFORM ALL REQUIRED CUTTING STATION FUNCTIONS:
  - ROBOT CONTROL
  - CUTTING
  - MARKING
  - MATERIAL POSITIONING AND CLAMPING
- TWO AUTOMATIX AID-600 ROBOTS:
  - MOUNTED OF TRAVELING SWIVEL BASE
  - SERVING PARALLEL CONVEYORIZED CUTTING TABLES
- ROBOTS FITTED WITH:
  - THERMAL DYNAMICS CORP PAK-45 PLASMA ARC CUTTING EQUIPMENT
  - ROTARY SCRIBE FOR FIT-UP AND BEND MARKING

AUTOMATED PROPELLER OPTICAL MEASUREMENT SYSTEM

- CURRENT METHOD OF MANUAL MECHANICAL MEASUREMENT EXTREMELY SLOW
- YIELDS NO COMPUTER COMPATABLE DATA — REQUIRES MANUAL ENTRY
- APOMS PROVIDES MUCH MORE RAPID AND ACCURATE OPTICAL INSPECTION (AVERAGE REDUCTION TO 8 HOURS FROM 300 HOURS)
- COMPARISON WITH CAD/CAM DATA FILE
- FEEDBACK TO DESIGN PROCESS
- CREATION OF NON-EXISTENT DATA FILE
- CONTRACT LET SEPTEMBER 1980 ROBOTIC VISION SYSTEMS, INC
- PROJECT DEMONSTRATION SCHEDULE FOR DECEMBER 1983

TARGET PRODUCTION RATES/8 HOUR SHIFT

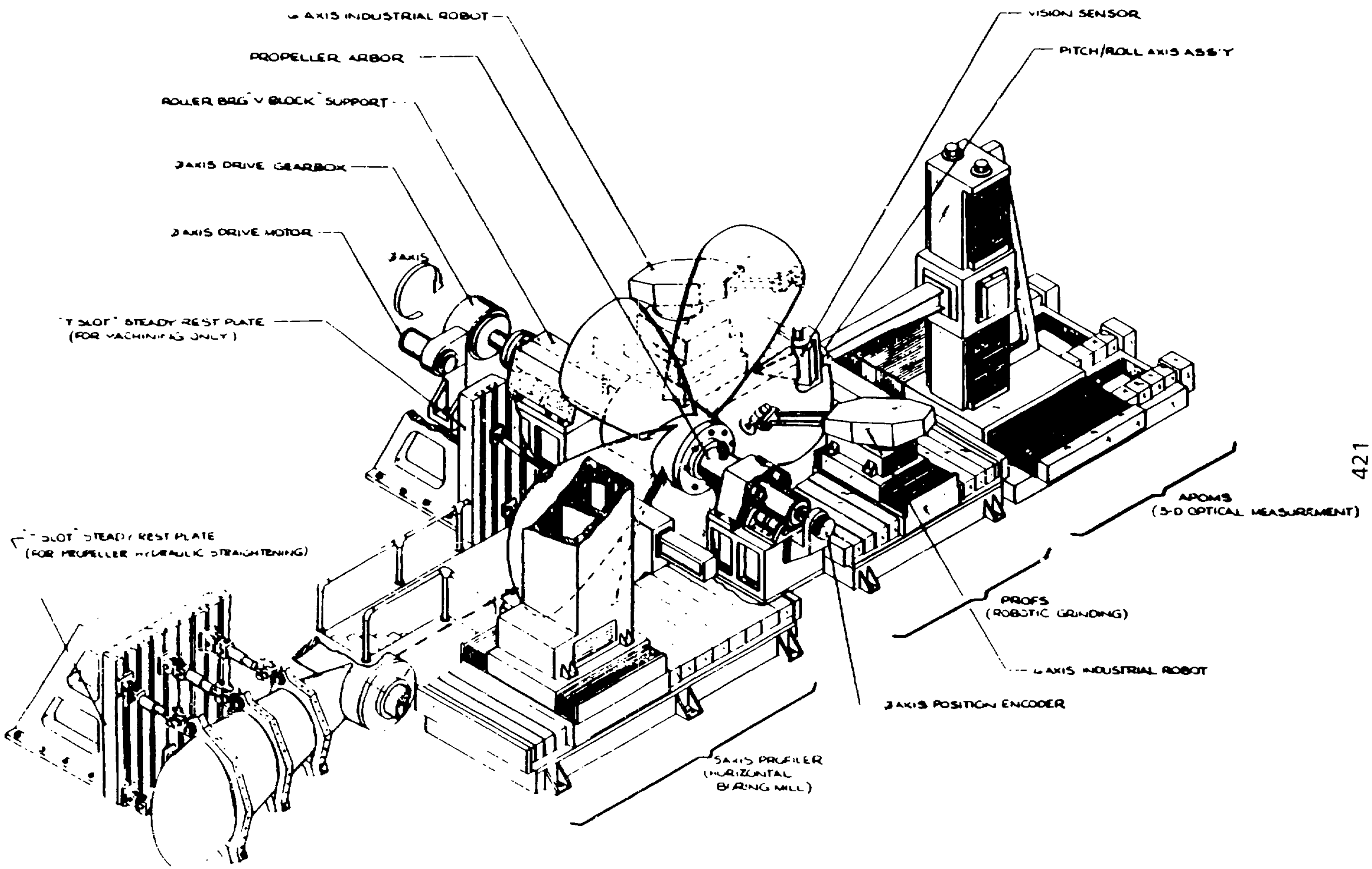
• RAW BARS	70
• FINISHED PIECES	331
• INCHES OF CUTTING	9000
• INCHES OF MARKING	500
• ACCURACY	+/— 1/16 INCH

SIMPLIFIED OUTLINE OF PROPELLER MANUFACTURING PROCESS

- DESIGN
- CAST
- INSPECT ROUGH CASTING
- INSPECT
- CHISEL SIZING CUTS
- GRIND OUT/WELD UP
- FINAL INSPECTION

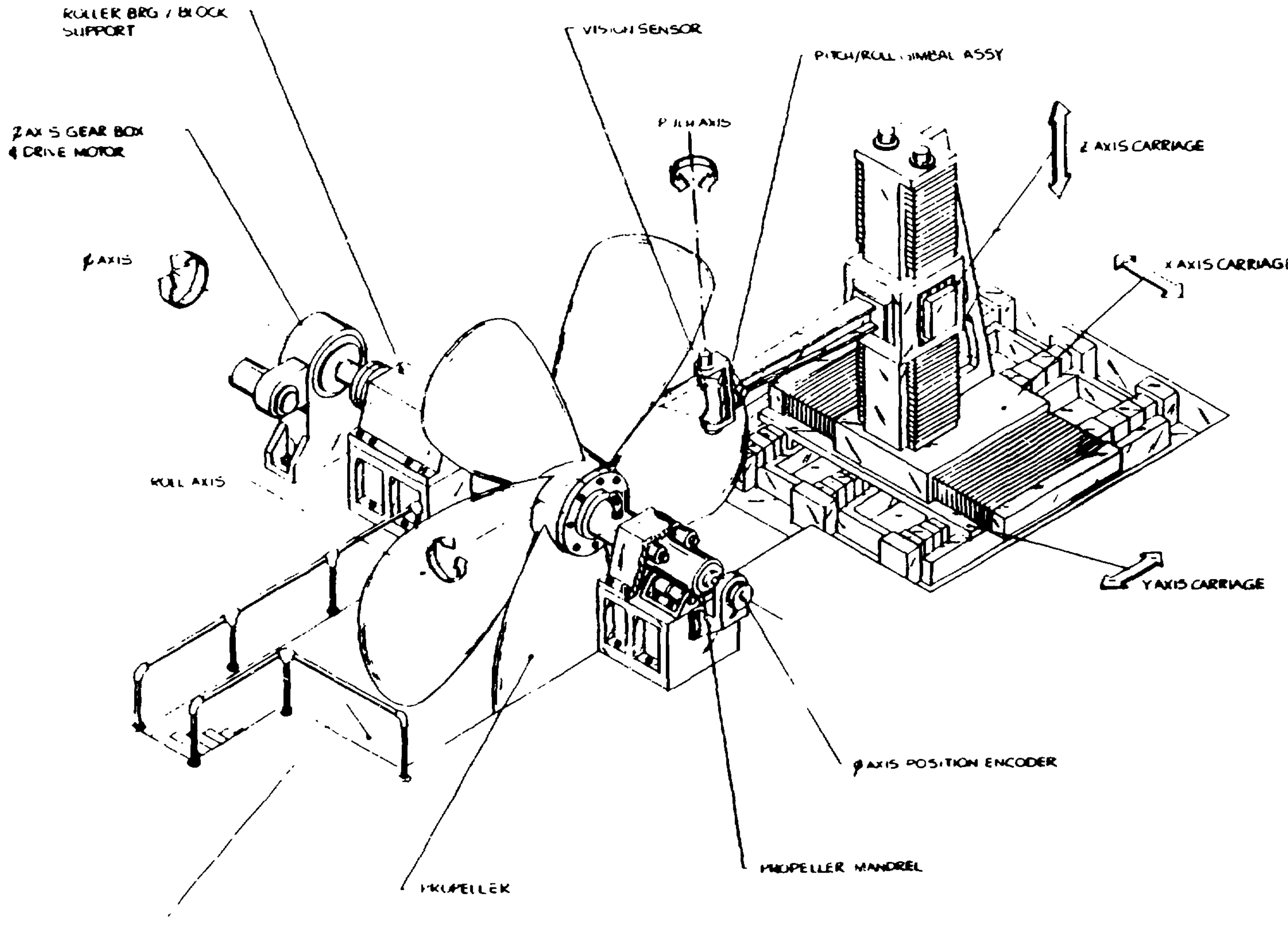
PROPELLER AUTOMATED WELDING AND FINISHING

- RAPID AUTOMATED ROBOTIC WELDING
- UNIFORM AND ACCURATE WITH MINIMUM BLADE DISTORTION
- AUTOMATIC AND ACCURATE MACHINING AND GRINDING
- AVERAGE OF 3300 MANHOURS REDUCED TO 300 HOURS USING TWO ROBOTS



ROBOTIC VISION SYSTEMS, INC.

536 Broad Hollow Road • Melville, New York 11747



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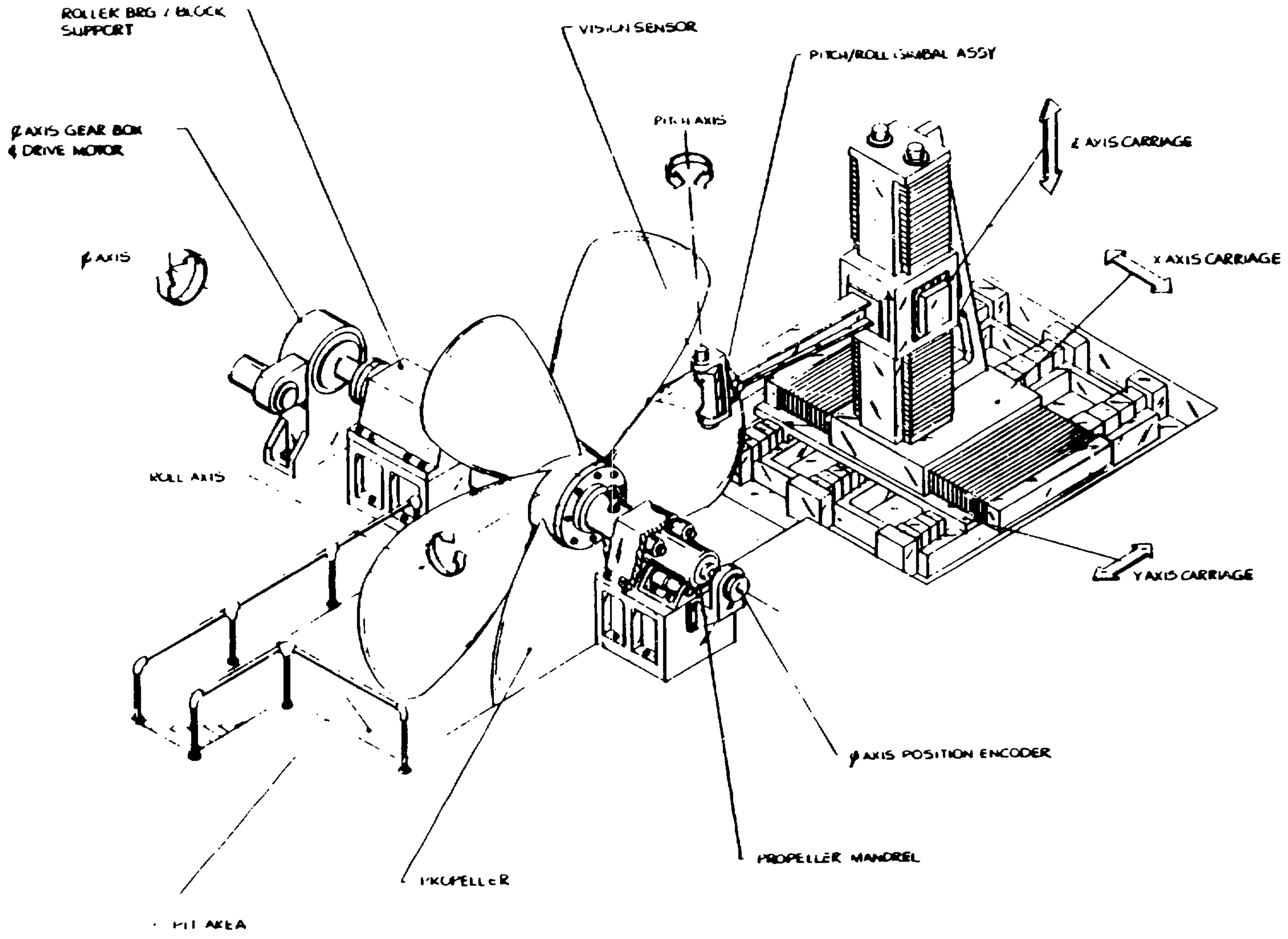


ROBOTIC VISION SYSTEMS, INC.

536 Broad Hollow Road • Melville New York 11747

ARTICULATING ROBOTICS FOR LASER ASSISTED METALWORKING

- DEVELOP A ROBOTIC CAPABILITY FOR MANIPULATING A LASER BEAM FOR WELDING AND CUTTING, ETC.
- AUTONOMOUS, PROGRAMMED, OR MANUAL OPERATION
- ABILITY TO ADJUST WELDING PARAMETERS IN REAL TIME
- REAL TIME WELDING INSPECTION, CORRECTION, AND DOCUMENTATION
- TRANSLATION BETWEEN SEVERAL WORK STATIONS

PROJECT MANAGER: DR. HENRY WATSON
NAVAL RESEARCH LAB
(202) 767-2622

IMPORTANT PARAMETERS

• WORK ENVELOPE	20 FT x 20 FT x 10 FT
• MODES OF OPERATION	MANUAL TEACH OFFLINE PROGRAMMING AUTOMATIC
• TRACKING PRECISION	X — ± 0.005 IN Y — ± 0.005 IN Z — ± 0.015 IN θ — ± 1.0 DEG
• WELD SPEEDS	0-200 IPM

SCHEDULE AND FUNDING PROJECTIONS

ADVERTISED IN CBD	27 OCT 1982
REQUESTS FOR PROPOSAL MAILED	29 NOV 1982
CLOSING DATE FOR PROPOSALS	18 JAN 1983
CONTRACTOR SELECTED (PROJECTED)	JUN 1983
CONTRACT DURATION (EXPECTED)	3 YEARS
PROJECTED COST	7 - 10M

VISION ASSISTED ROBOTIC WELDER

- DEVELOP PROTOTYPE VISION SENSOR FOR CONTROLLING ROBOTIC WELDER
- DEVELOP FAST MANUAL PROGRAMMING SYSTEM
- CONTRACT LET WITH SRI INTERNATIONAL, MENLO PARK, CA
- SUBCONTRACT WITH TODD SHIPYARDS, SAN PEDRO, CA

PROJECT MANAGER: BOB JENKINS
DTNSRDC CODE 1853
(202) 227-1363

FAST MANUAL PROGRAMMING UNIT

- CONTROL BOX WITH PROPORTIONAL JOYSTICK
- REPLACES TEACH PENDANT
- SIGNIFICANTLY REDUCES PROGRAMMING TIME

Vision Assisted Adaptive Robotic MIG Welding System

Goal: To Develop a Prototype Integrated System With:

- Real Time
  - Detection
  - Correction
  - Documentation
- Several Modes of Operation
  - Autonomous
  - Off-Line Program
  - Manual

Approach: Integrated Ongoing Related Navy Projects With Industrial Contractor Efforts

Project Manager
Bob Jenkins
DTNSRDC Code L853
(202) 277-L363

Required Elements

(1) 3-D Vision Sensors (Geometric Data)

(2) 2-D Vision Sensor (Tracking & Process Control)

(3) Artificial Intelligence (Expert Systems)

(4) Robot

(5) Robot Controller

(6) Process & Environment Sensors

(7) Weld Controller

(8) Off-Line Programming Capability (CAD/CAM Interface)

(9) Standardization of Above

Removed Perspective 3-D Vision System

(1) Geometric Awareness of Entire Working Envelope

(2) Rough Initial Positioning

(3) Shape Classification

(4) Collision Avoidance

Localized 3-D Vision System

(1) Slightly Ahead of the Weld

(2) Seam Tracking

(3) High Precision 3-D Measurements

(4) Plane Matching for Surface Identification

(5) Calculation of Surface Normals,
Intersections, Etc.

Localized 2-D Vision System

(1) Looks at the Weld Pool

(2) Precise Seam Tracking

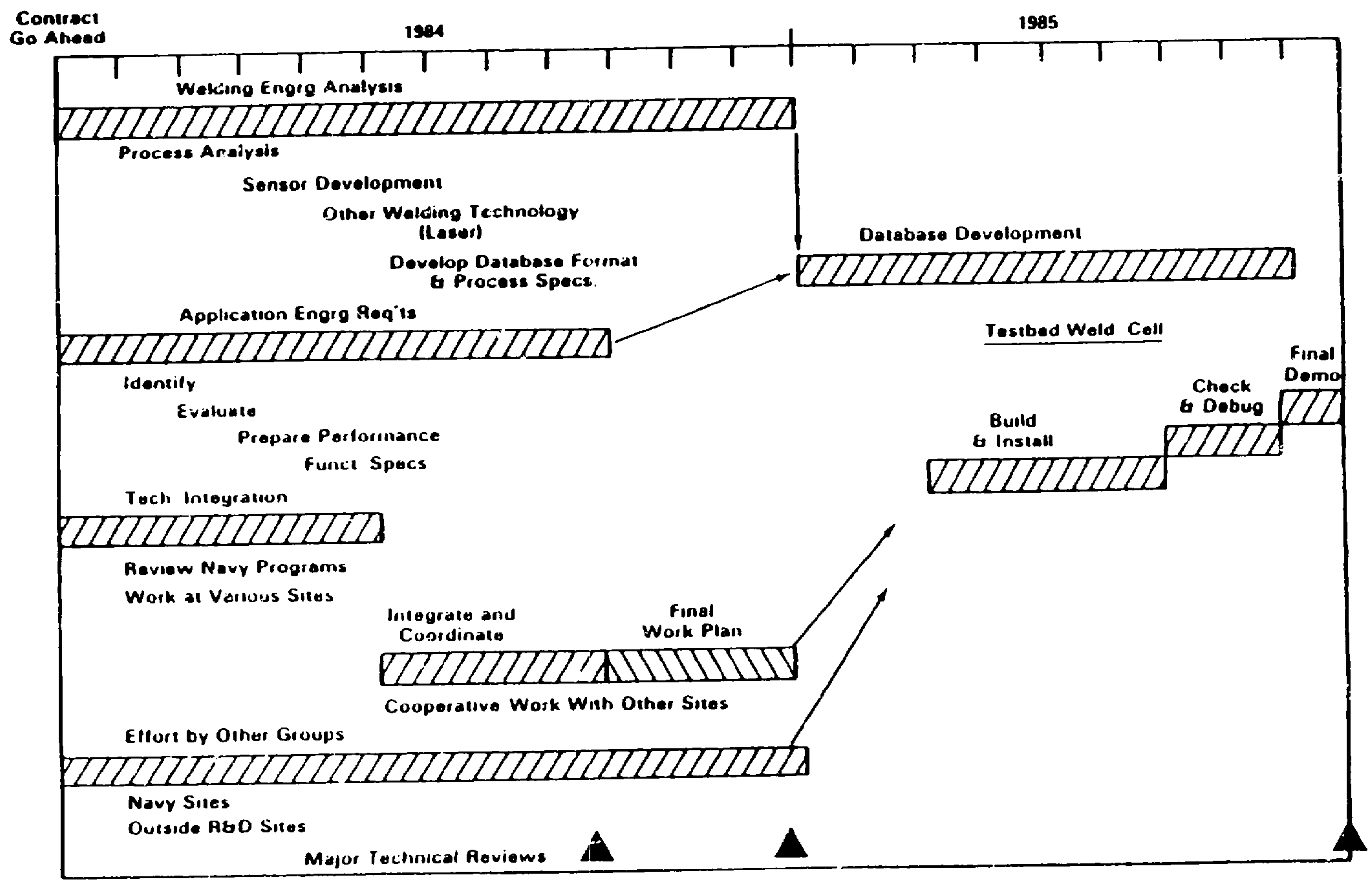
(3) Process Control

Navy Assets

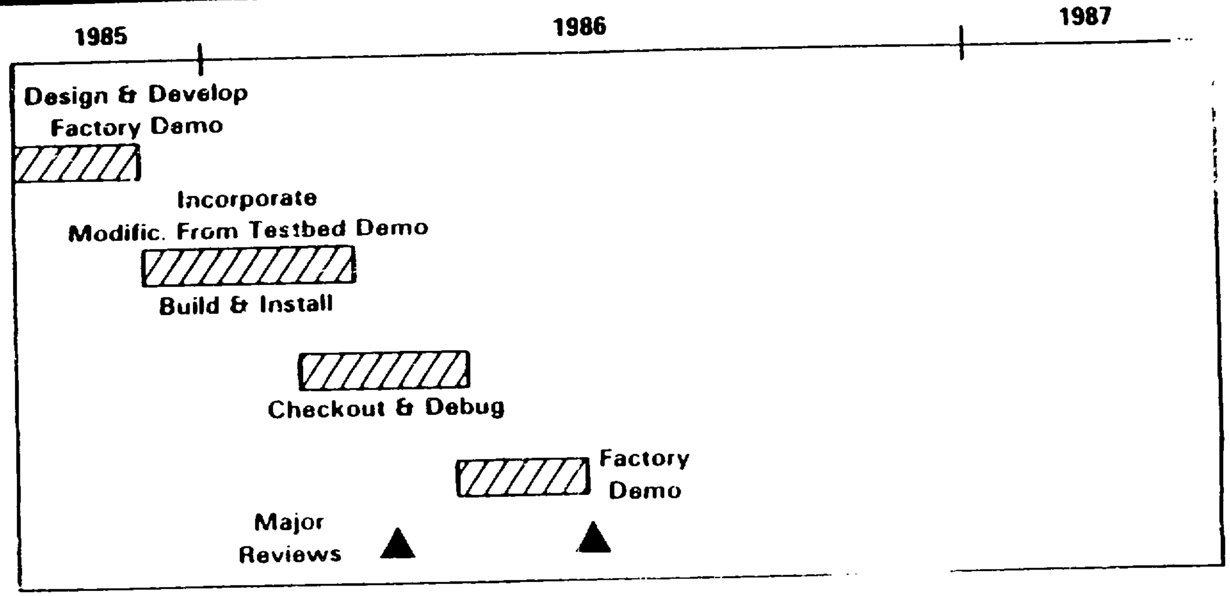
- DTNSRDC
  - 3-D Vision Effort (SRI)
  - Tech Option for Weld Process Control
  - Spectographic Monitor (Army)
- NOSC
  - Artificial Intelligence (Expert System)
  - MIT Work in Process Control
- NSWC
  - 3-D Vision Effort for Work Envelope
- ONR
  - Related Research Efforts
- NAVSEA 07
  - 3-D Vision Effort (RVSI)
- NBS
  - Standardization

$\boxed{\text{Coordination To Be Effected by NAVSEA Council}}$

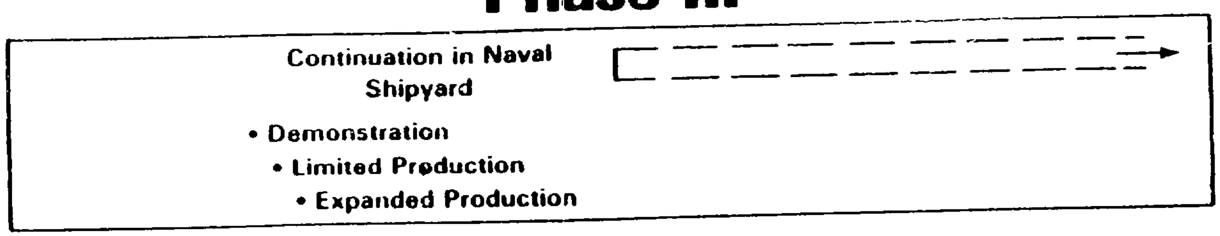
Integrated Flexible Welding System
Phase I



Integrated Flexible Welding System
Phase II



Phase III



--ABSTRACT--

NAVAL ORDNANCE COMMUNITY ROBOTICS APPLICATION AREAS

By: H. Peesel

Naval Sea Systems Command

"The Robotics Workshop has been beneficial to the ordnance community," said Mr. Peesel. The nine ordnance activities of the Navy have identified twenty-three robotics application areas with sixty-two potential applications. Three of these applications have been accomplished, several are in process; the remainder constitute the unexploited agenda of opportunity for cost savings and productivity enhancement. Robotics is looked at by the Navy Ordnance Community primarily as a productivity improvement device with attendant labor and material savings.

The process environment at the weapons stations is essentially that of maintenance and repair, rather than new item manufacture. The products supported have not been designed to be compatible with automation-aided support systems. There is a very broad product line with a multiplicity of military customers. Process quantities are low, with lot size "one" predominant. What is needed is robotics hardware that is easy to program. Also needed is a high degree of flexibility, due to the broad product range and small lot sizes encountered; this implies multiple product usage for robotized work stations and cells. Also, the setup costs for alternate configurations must be low. Turnkey system implementations are appropriate because of the rather moderate level of expertise in automation and robotics in the naval ordnance community. Private sector support is thus needed to develop the broad family of applications resident in the ordnance activities, and strong technical support for this important effort was solicited by the speaker.

SUPPLY CENTER PROCESSES

BY: A. SENHEN

AD-P004 014

DOD ROBOTICS APPLICATION WORKSHOP
4-7 OCTOBER 1983, SACRAMENTO, CALIFORNIA
PRESENTATION
NAVAL SUPPLY CENTER, SAN DIEGO

Slide 1

The Naval Supply Centers are the box kickers of the Navy. They supply the material needs of the fleet and shore activities including virtually all parts, provisions, and fuel needed to sustain day-to-day operations. (The Supply Centers are not responsible for maintaining or distributing ordnance). There are seven Supply Centers in the continental United States and three smaller, supply depots throughout the world. Each is responsible for supporting its assigned customers. Although we represent only the San Diego Center, the operations of other centers and depots are similar.

The San Diego Center is spread over five sites from Long Beach to the Mexican border and supports about one-fourth of the Navy's fleet. We maintain approximately one quarter of a million individual items ranging from tiny electronics spares to ship's boats and from hand tools to vegetable soup. Our largest Supply Center, Norfolk, maintains over a million and a half items.

Slide 2

This slide presents a breakdown of the major functions performed by the Center. As you can see, about 20% of the Center's total operations lend themselves to process analysis for potential robotic applications. All involve material handling or movement.

Slide 3

These are:

- Receiving - Physically examining material to determine what the material is, what condition it is in, and its intended destination.

- Routing - Moving the material received to the proper location (building) for storage or to a local or distant customer for direct turnover material or trans-shipment.

- Storage - Placing the material in a bin, on a shelf, in a pallet opening or other accountable location.

- Picking - Selection of the right amount of the right material of the right condition of the right shelf life.

- Routing to staging - Moving the material to a location to be consolidated with other material for the same customer or geographic location.

- Routing to Customer/Shipping - Movement of material directly to local customers or an area where orders are specially packed for distant shipment.

- Shipping - Overpacking and consolidation by geographical area.

- Special Operations - The above processes generally each involve a separate organizational entity responsible for that, and only that, process. Emergency needs and rewarehousing operations involve a number of the above processes but are the individual responsibilities of a single organizational unit or even a single individual. In addition, a perpetual inventory function is performed to improve the accuracy of the operation and to comply with legal requirements. By law this cannot performed by the same people who perform the above processes.

<u>SLIDE 4</u>

These processes are analyzed in the matrix form requested by the Workshop organizers. It is believed that a significant potential exists

for robotics at the Supply Centers if some minor technical problems can be solved.

During the period from the late 1950's to the mid 1970's, the Supply Centers and their parent command, the Naval Supply Systems Command concentrated their developmental efforts primarily on a computer-based, order-processing, inventory control, and management information system, called UADPS-SP. Then in the mid 1970's, it became apparent that a large potential for improvement existed in physical material handling (or material distribution). With a few notable exceptions, the last major aid provided up to this time was the fork lift.

Since then, we have seen the use of newer handling aids such as:

- SLIDE 5

Pallet Conveyor,

- SLIDE 6

Carton Conveyor,

- SLIDE 7

Bar Code Technology, and

- SLIDE 8

Automated Guided Vehicle Systems.

Some of these tools were installed piecemeal as the demands of time or the availability of funds dictated, but others,

- SLIDE 9

Such as NISTARS (being installed at the big three Centers, San Diego, Norfolk and Oakland) and the Automated Materials Management Control System for provisions at San Diego are Hard Automation which integrates all (or most) of the supply processes and is under the control of a computer.

The acronym "NISTARS" stands for "Naval Integrated Storage, Tracking, And Retrieval System." It will contain each Center's most active material which has a unit cube smaller than a standard pallet (40"W X48"L X67"H). At San Diego, capacity will be available to handle at least 200,000 small items (up to 6" X 4" X 4"), 130,000 medium-sized items (up to 30" X 24" X 24" and under 55 lbs.) and 6300 pallet loads. In addition to the other tools of modern physical distribution, NISTARS incorporates:

- SLIDE 10

Human-engineered Stow/Issue Stations, interfacing with

- SLIDE 11

Robotic storage and retrieval cranes/racks,

- SLIDE 12

Man-aboard storage and retrieval cranes equipped with intelligent, multi-functional terminals,

- SLIDE 13

Tilt-tray sorters,

- SLIDE 14

And carousel-based consolidation work stations. NISTARS is scheduled for delivery in 1984.

These tools have resulted in improved performance at less cost but have also produced "Islands of Automation." It is here we feel that the first general purpose robots could be used. In addition, it should be noted that most of the hard automation is off-the-shelf, existing technology. As a result, the system designers have always had at their disposal when a task was "too hard" or an off-the-shelf answer

wasn't available, that multifunctionoid of the utmost flexibility - a human.

- <u>SLIDES 15, 16 & 17</u>

Consider this operation. A multi-carton pallet arrives at the end of a conveyor line. Each carton must be removed from the pallet, have a bar code attached, and be placed, individually, on a takeaway conveyor. An easy, but boring and repetitive task for a human. For a robot however, it is not so easy. The carton dimensions may vary from about 10" X 10" X 10" to about 20" X 24" X 24" - hundreds of combinations - and the stacking geometry can vary by a possible three different ways within a single, fixed dimension.

- <u>SLIDE 18</u>

This plan view presents the geometry of the problem.

- <u>SLIDES 19, 20 & 21</u>

The second potential robotic application involves picking up cartons or tote boxes (containing non-self-conveyable material) from one of the two carton in-feed conveyors and placing the material on an individual t tray with the bar code aligned to plus or minus fifteen degrees from the direction of tray travel. If a tote box is involved, it must be placed on the takeaway conveyor with proper bar code alignment. The up-left conveyor, containing unreadable bar codes from the tilt trays may also be within the robot's tasking, although a multi-try no-read will probably require human correction.

- <u>SLIDE 22</u>

This plan view presents the geometry of the problem. Again, the high variability of size and weight make this task more difficult for a

robot. The use of tactile sensors should solve the variability problem. We feel that these two applications are feasible for robotics with a payback of less than three years, and if successful, are generic enough to adapt the experience of other, similar applications.

In the future, we can see the applicability of vision-based bin picking systems such as that now being prototyped by General Electric.

In summary, while hard automation with computer control is the foundation for physical distribution modernization, we believe robotics also has a role in improving the productivity, accuracy, and customer response of the Navy Supply Establishment.

SUPPLY CENTER FUNCTIONS-NSCSD

	PEROENT OF WORKFORCE
CENTRALIZED ADMINISTRATIVCE SERCVICES (CONTRACTS, PAYMENT, ETC.)	25%
FUEL OPERATIONS	2%
PHYSICAL DISTRIBUTION (BOX KICKING, MATERIAL SUPPORT OF CUSTOMERS LOCAL & DISTANT)	21%
PHYSICAL DISTRIBUTION QUALITY ASSURANCE	1%
ADMINISTRATION & OTHER CENTER OPERATIONS	50%

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2/NSCSD -C- 4 OCT 83

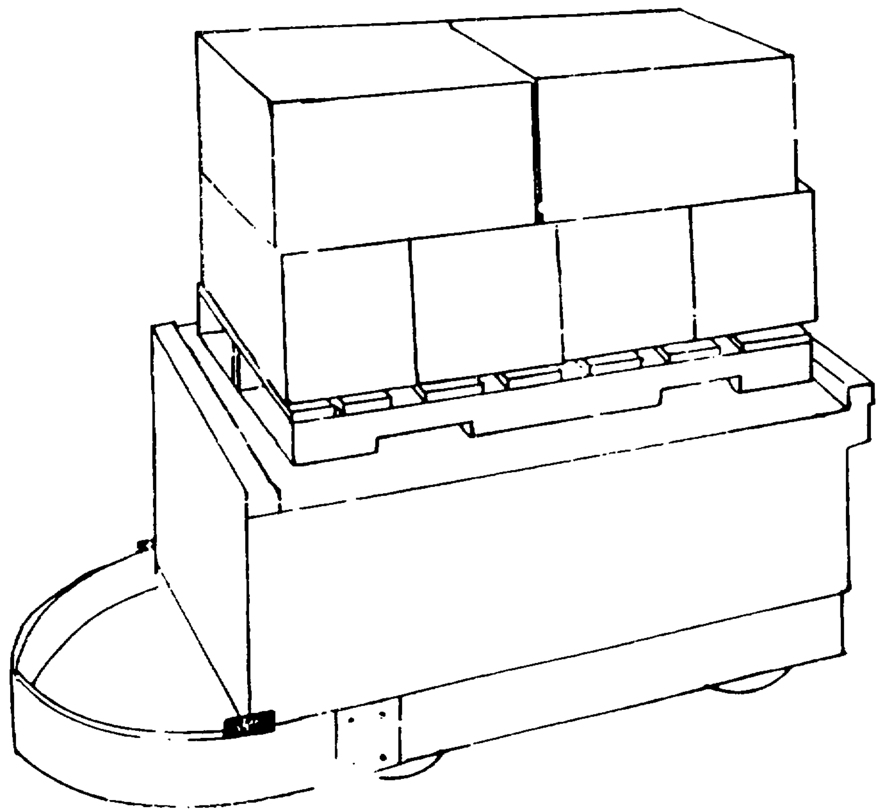
SUPPLY CENTER PHYSICAL DISTRIBUTION PROCESSES

1. RECEIVING
2. ROUTING TO STORAGE/SHIPMENT/DELIVERY
3. STORAGE
4. PICKING
5. ROUTING TO STAGING
6. ROUTING TO LOCAL CUSTOMER/SHIPPING
7. SHIPPING (PACKING)
8. SPECIAL OPERATIONS– EMERGENCY INTERRUPT AND REWAREHOUSING

3/N3CSD -C- 4 OCT 83

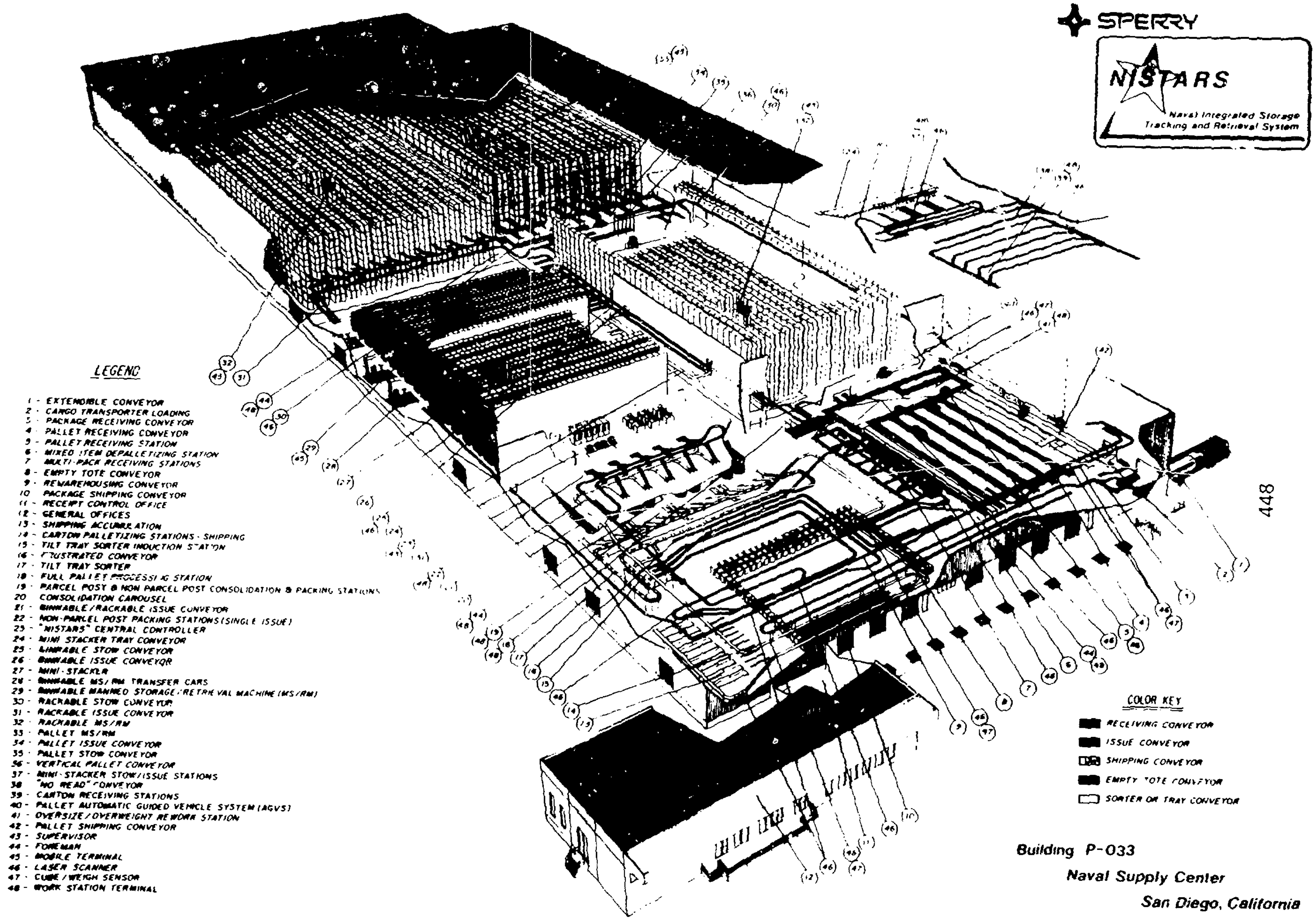
GENERAL PROCESS INFORMATION MATRIX-NSCSD

PROCESS	TOUCH LABOR HRS/YR (K)	TOTAL COST PER YR (K)	HAZARDOUS ENVIRONMENT?	LABOR SKILL REQ'D	JOB TRAINING	KEY OPNS COMMON?	REPETITIVE, BORING?	PRODUCT FRAGILE?
RECEIVING	66	$816	NO	MOD	6 MOS OJT	NO	NO	YES
ROUTING TO STORAGE	76	$912	NO	LOW	3 MOS OJT	YES	YES	YES
STORAGE	70	$852	SOME	LOW	do	YES	YES	YES
PICKING	125	$1488	SOME	LOW	do	YES	NO	YES
ROUTING TO STAGING	35	$444	NO	LOW	do	YES	YES	YES
ROUTING TO CUST./SHIPPING	97	$1212	NO	MOD	do	YES	YES	YES
SHIPPING (PACKING)	127	$1644	NO	MOD	6 MOS OJT	NO	NO	YES
SPECIAL OPS: EMERGENCY	5-10% TOTAL BUSINESS	5-10% TOTAL BUSINESS	SOME	MOD	3 MOS OJT	YES	YES	YES
REWAREHOUSING	19	$240	SOME	LOW	do	YES	YES	YES
INVENTORY COUNT	17	$216	NO	MOD	6 MOS OJT	YES	NO	N/A



AGVS VEHICLE

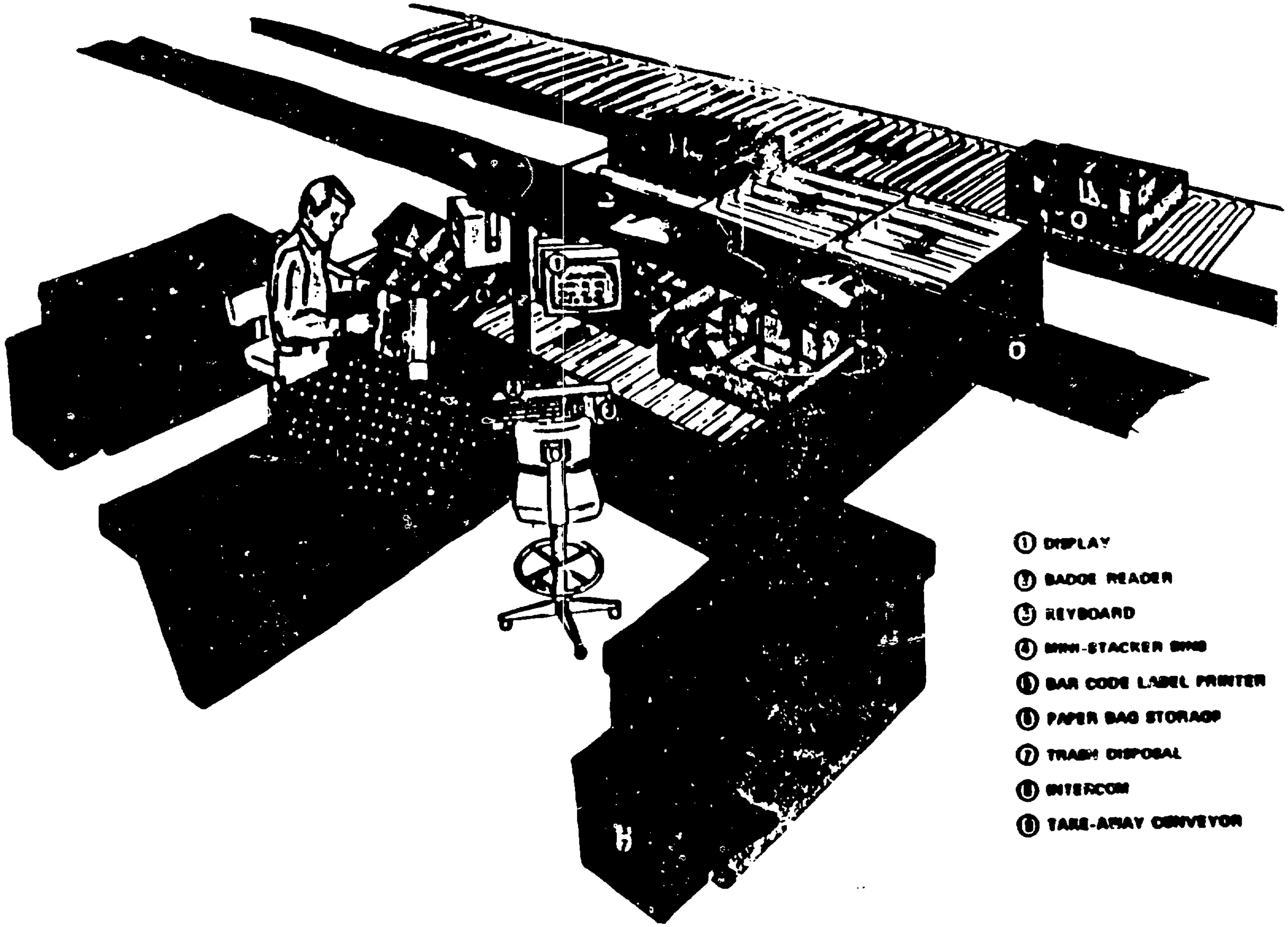
8/NSCSD-C-4 OCT 83



Building P-033
Naval Supply Center
San Diego, California

9/NSCSD-C-4 OCT 83

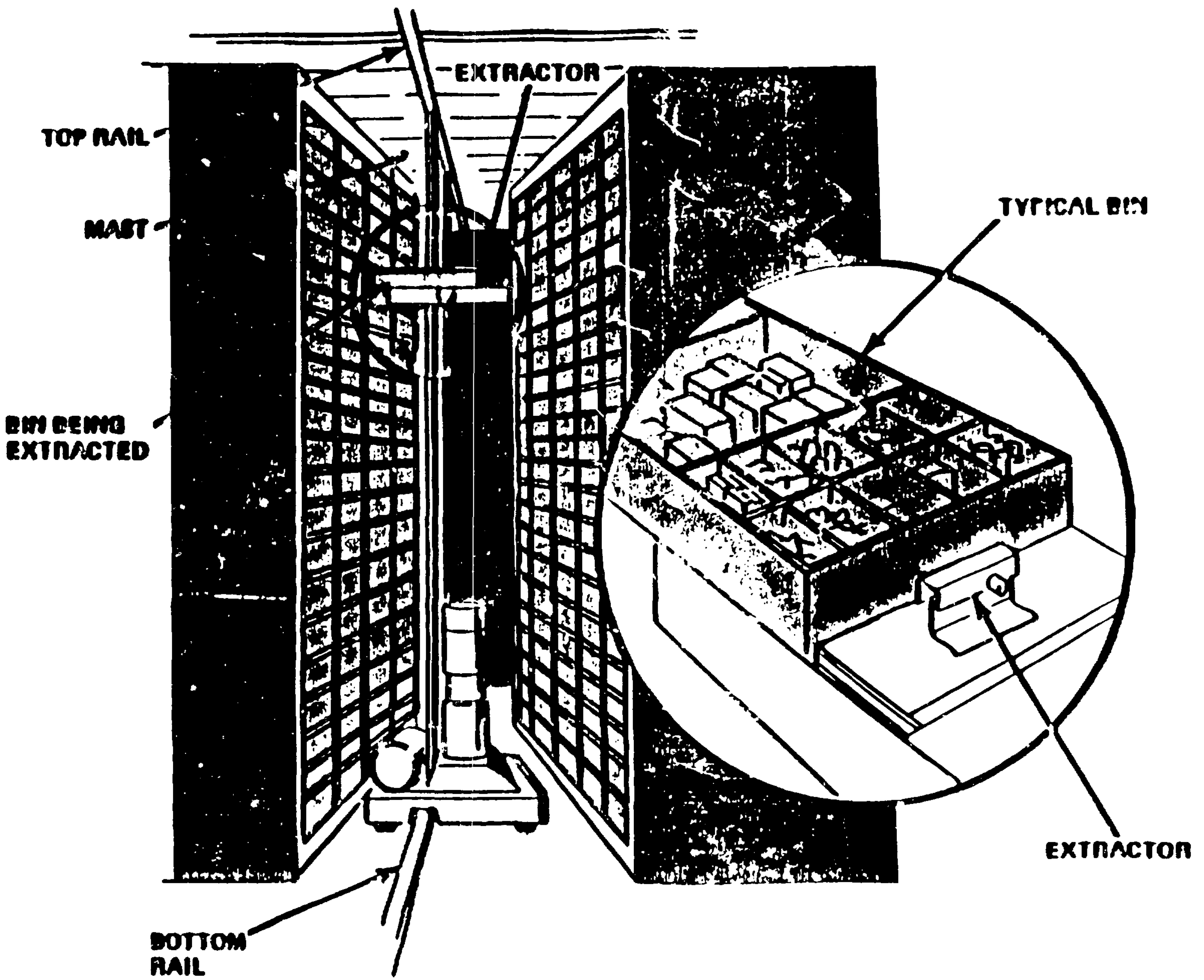
MINI-STACKER STATION



1 DISPLAY
2 BADGE READER
3 KEYBOARD
4 MINI-STACKER BINS
5 BAR CODE LABEL PRINTER
6 PAPER BAG STORAGE
7 TRASH DISPOSAL
8 INTERCOM
9 TAKE-AWAY CONVEYOR

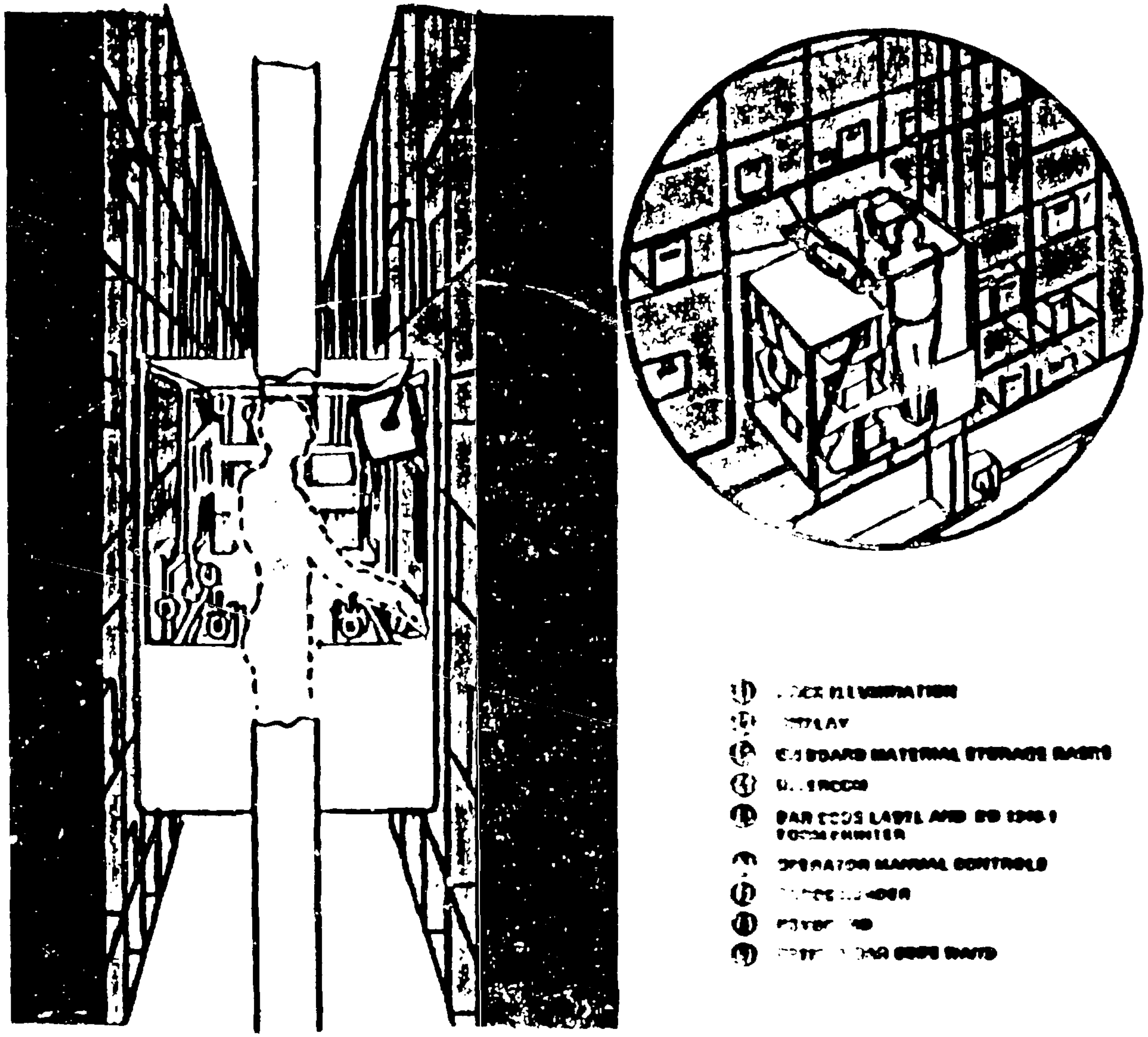
10/NSCSD-C-4 OCT 83

MINISTACKER



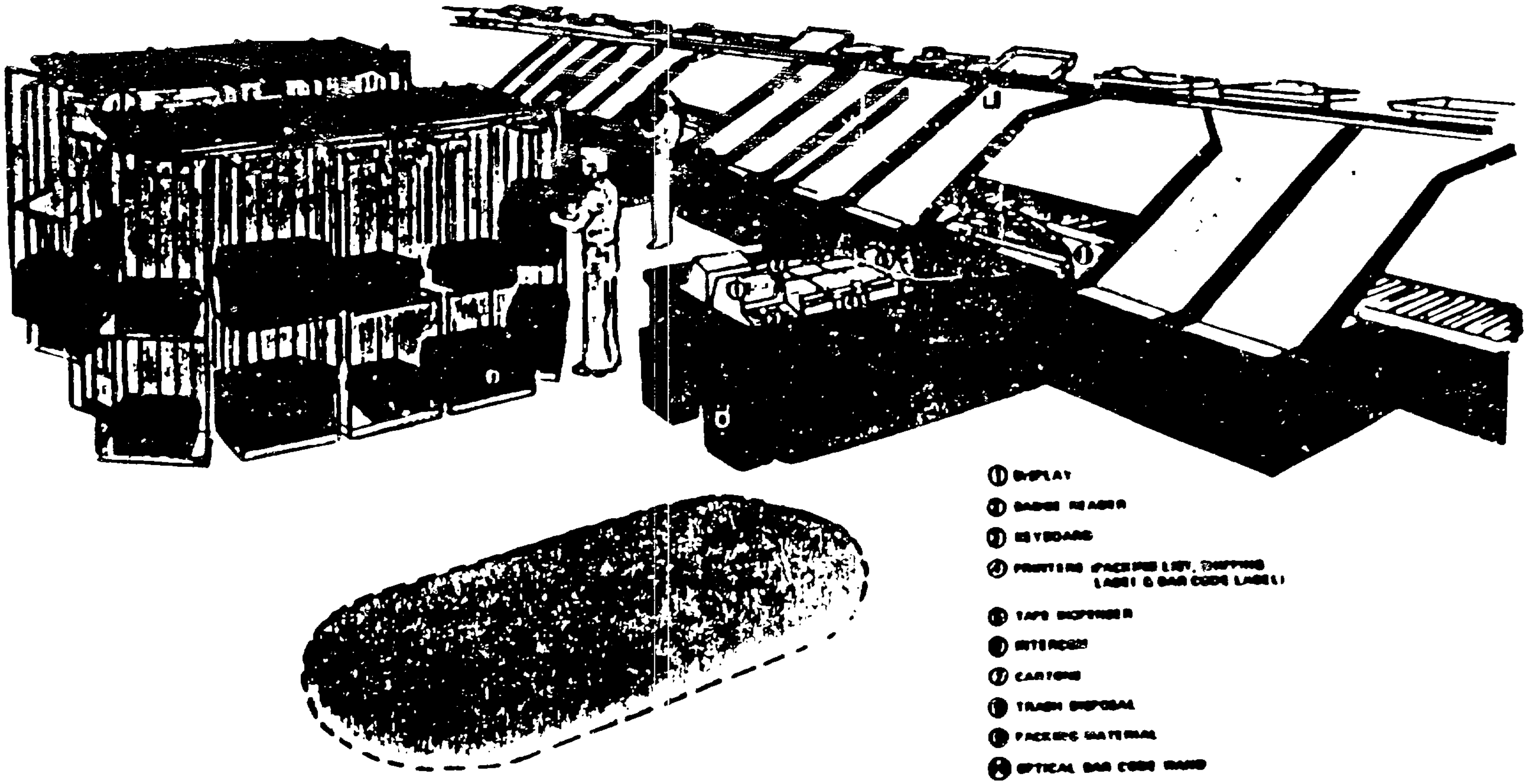
11/NSCSD-C-4 OCT 83

MANNED STORAGE RETRIEVAL MACHINE



1. [illegible]
2. [illegible]
3. [illegible] MATERIAL STORAGE [illegible]
4. [illegible]
5. BAR CODE LABEL AND DD [illegible] FORM PRINTER
6. OPERATOR MANUAL CONTROLS
7. [illegible]
8. [illegible]
9. [illegible]

CONSOLIDATION STATION



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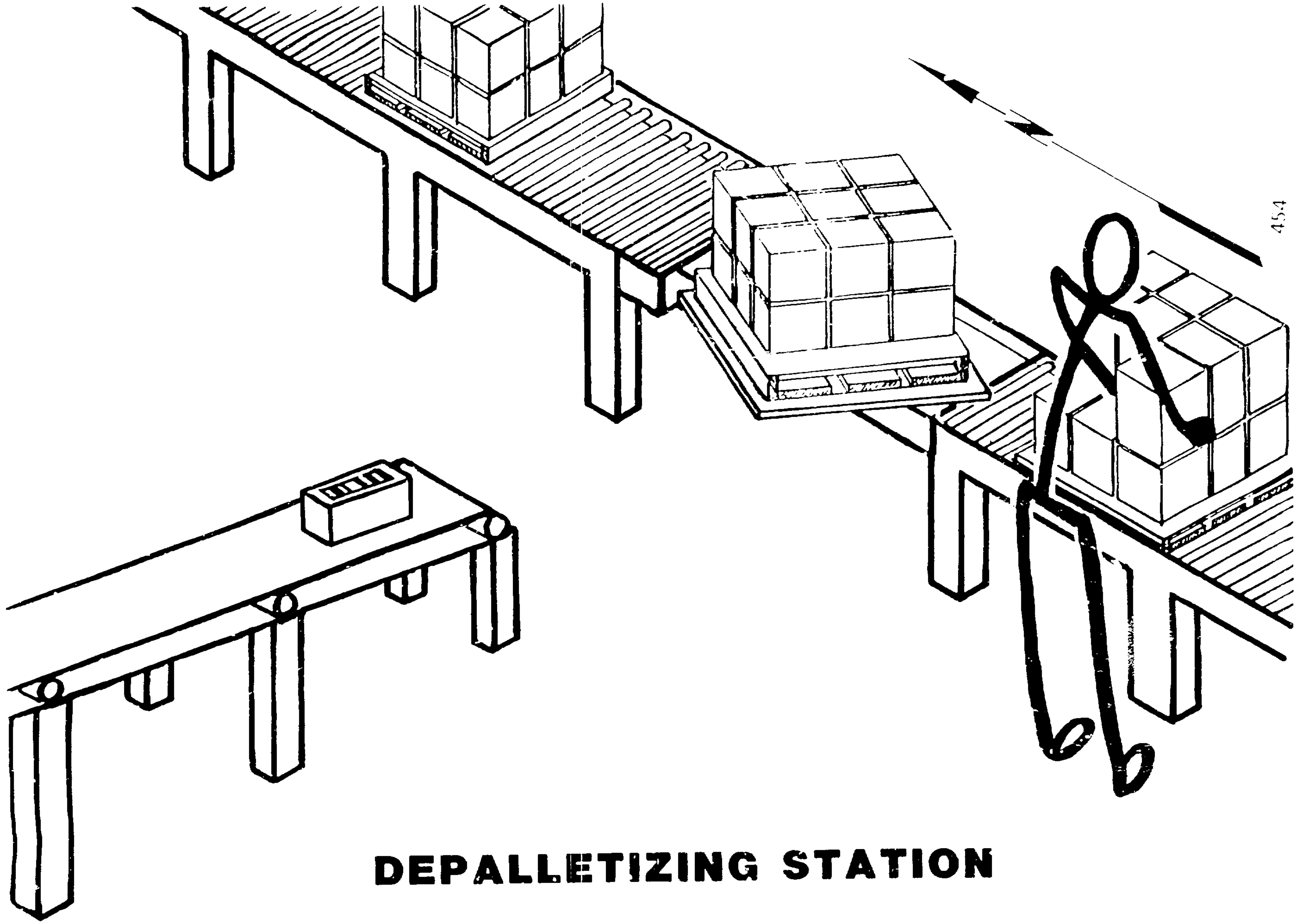
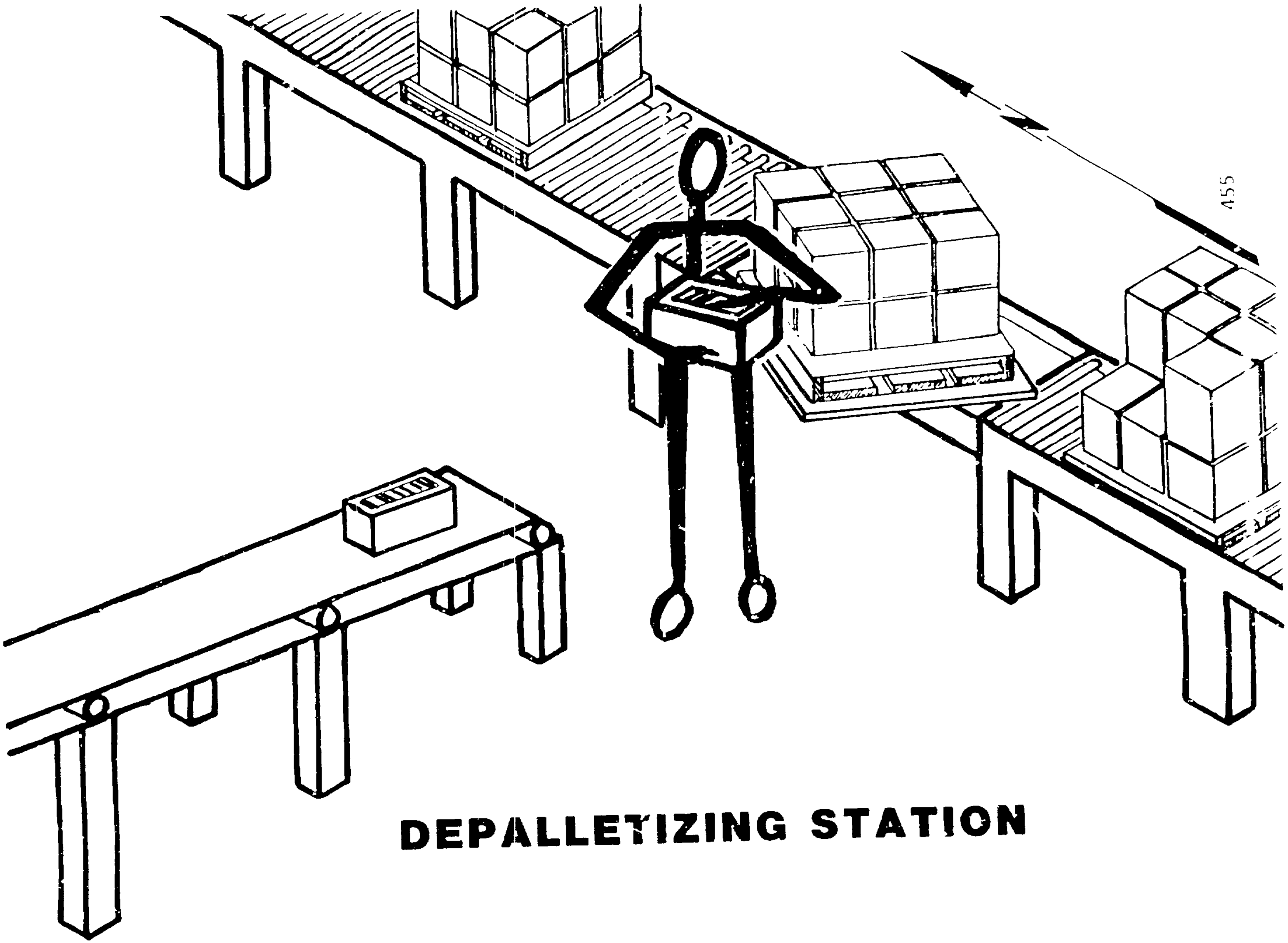
1. DISPLAY
2. BADGE READER
3. KEYBOARD
4. PRINTERS (PACKING LIST, SHIPPING LABEL & BAR CODE LABEL)
5. TAPE DISPENSER
6. INTERCOM
7. CARTONS
8. TRASH DISPOSAL
9. PACKING MATERIAL
10. OPTICAL BAR CODE WAND
11. TAKE AWAY CONVEYOR



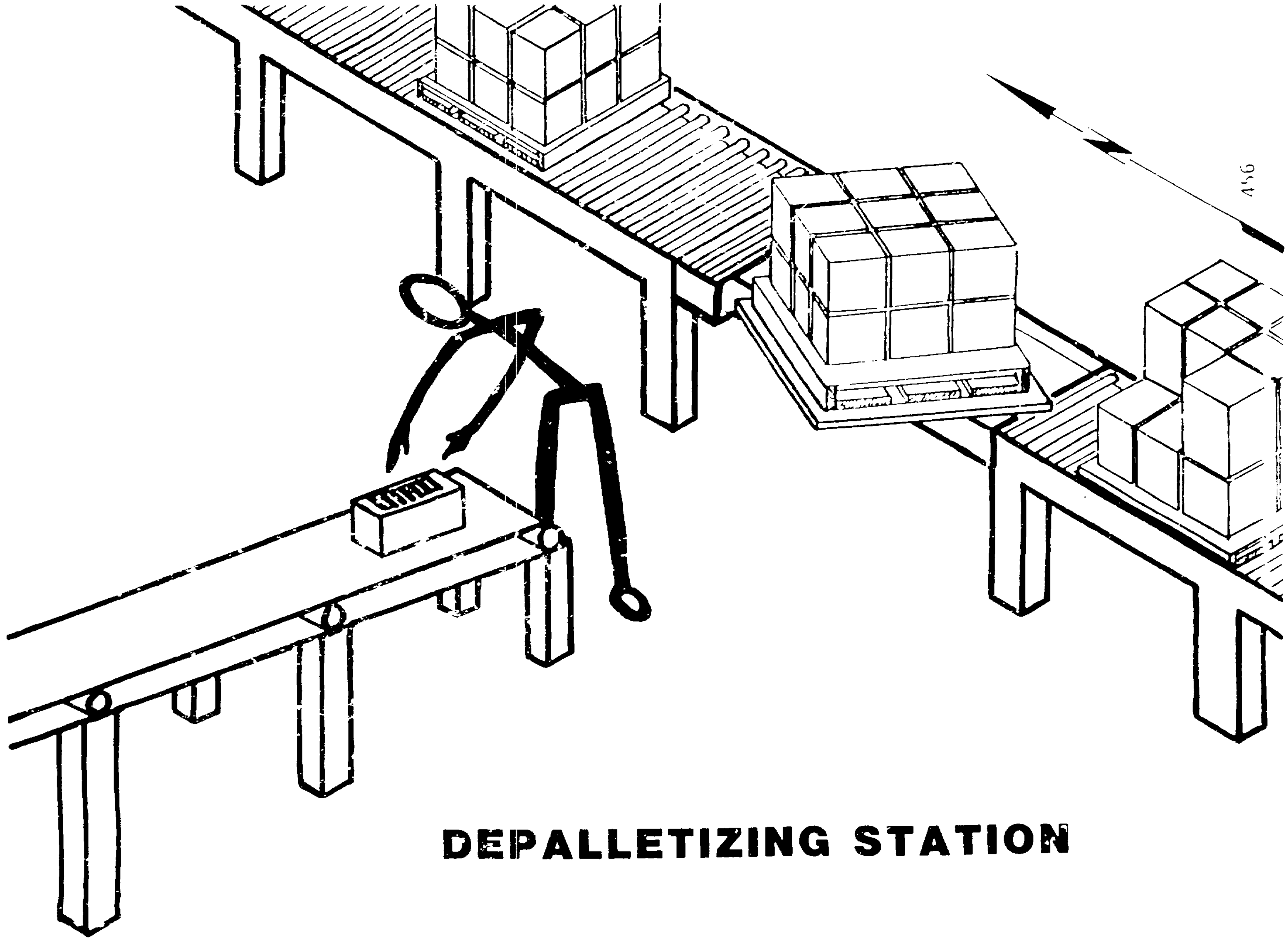
DEPALLETIZING STATION

15/NSCSD -C- 4 OCT 83



DEPALLETIZING STATION

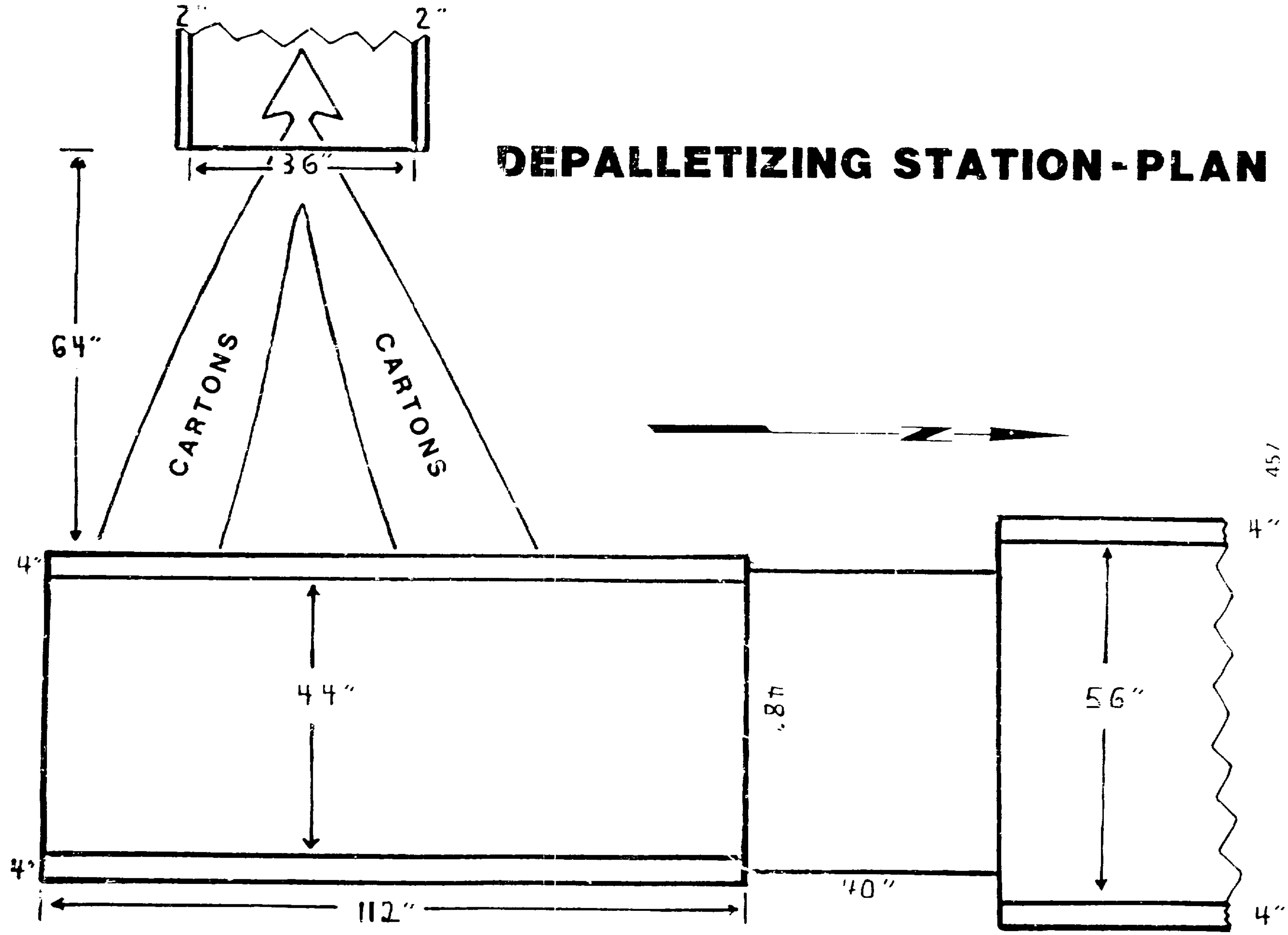
16/NSCSD -C- 4 OCT 83



DEPALLETIZING STATION

17/NSCSD -C- 4 OCT 83

DEPALLETIZING STATION-PLAN



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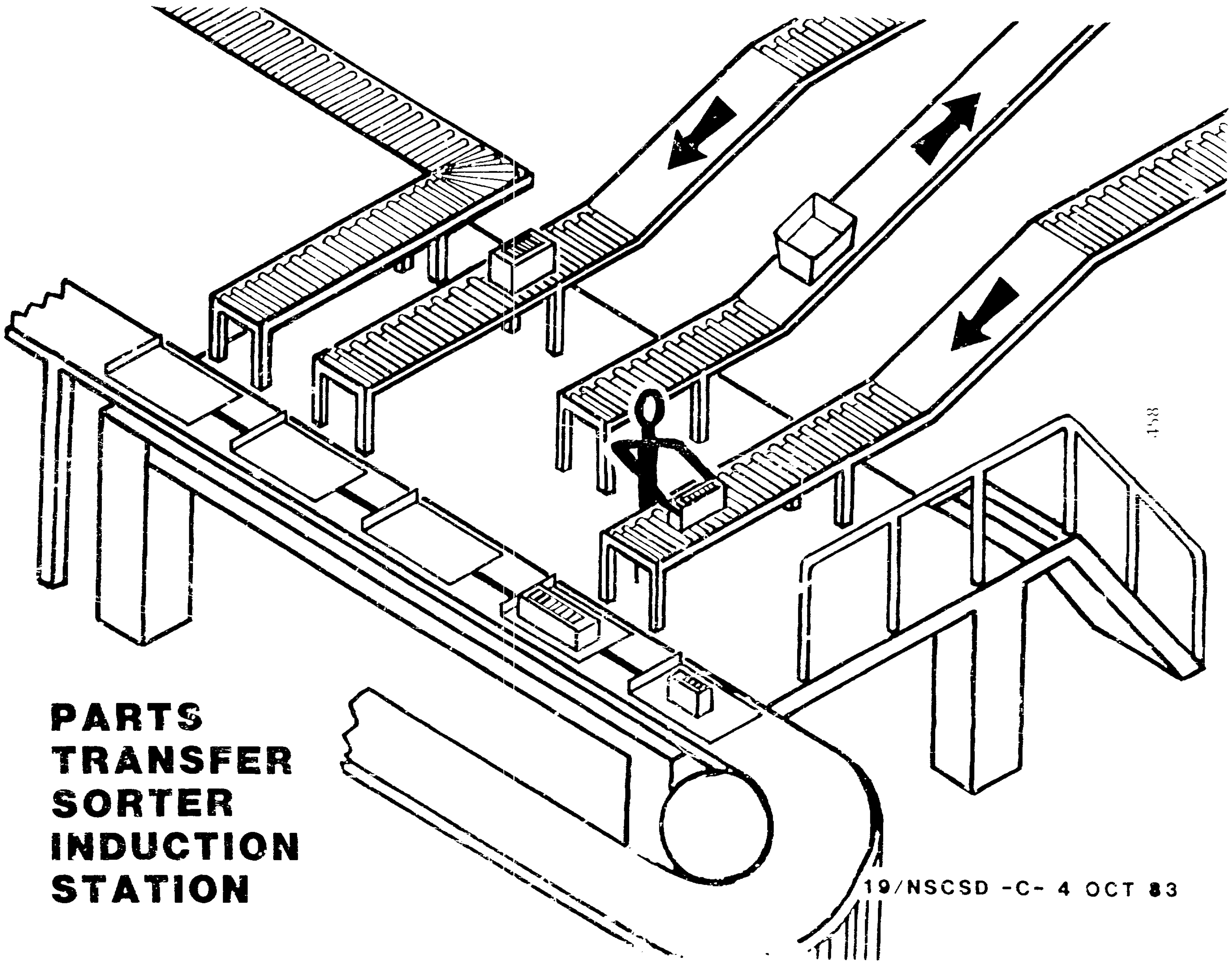
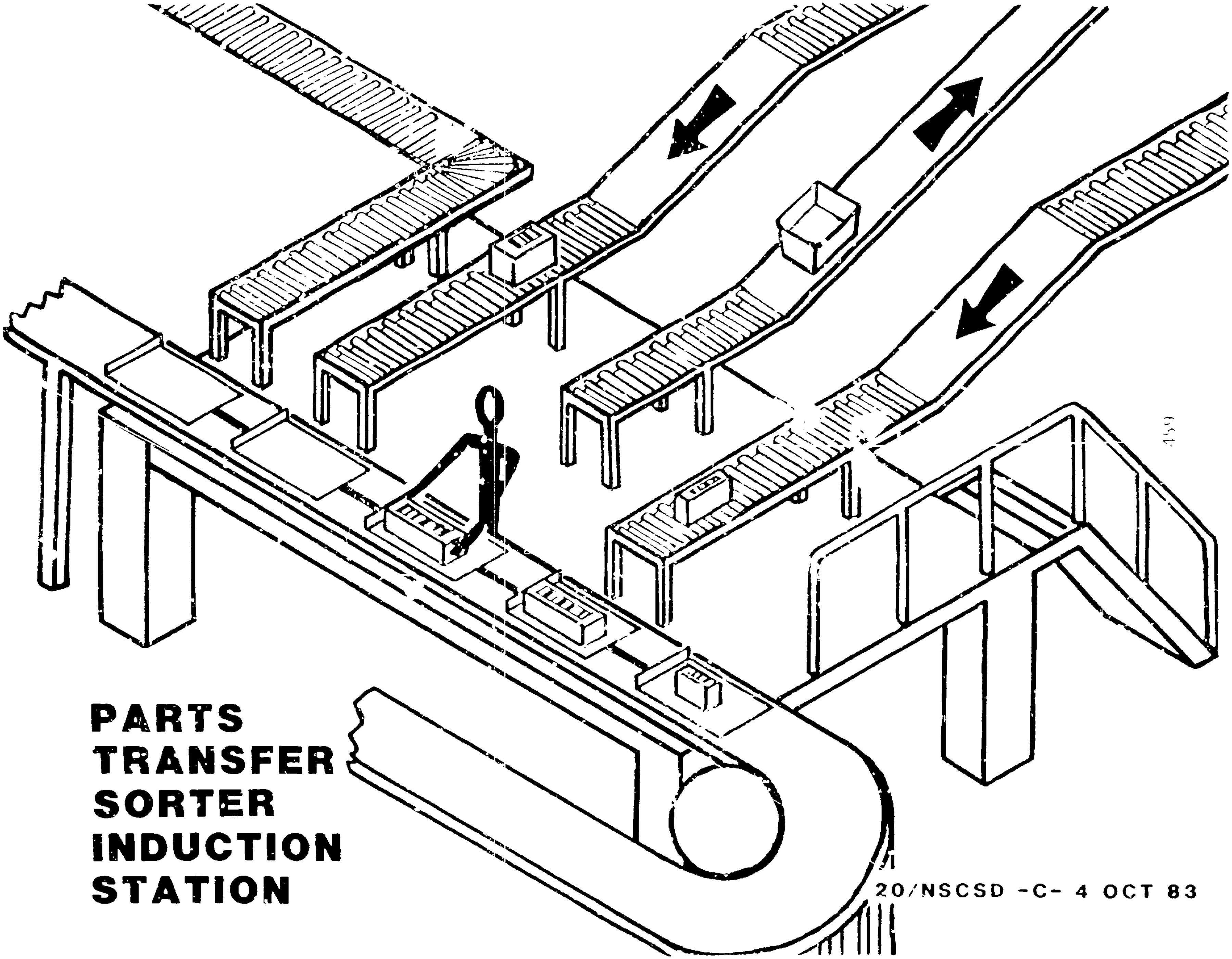
18/NSCSD -C- 4 OCT 83



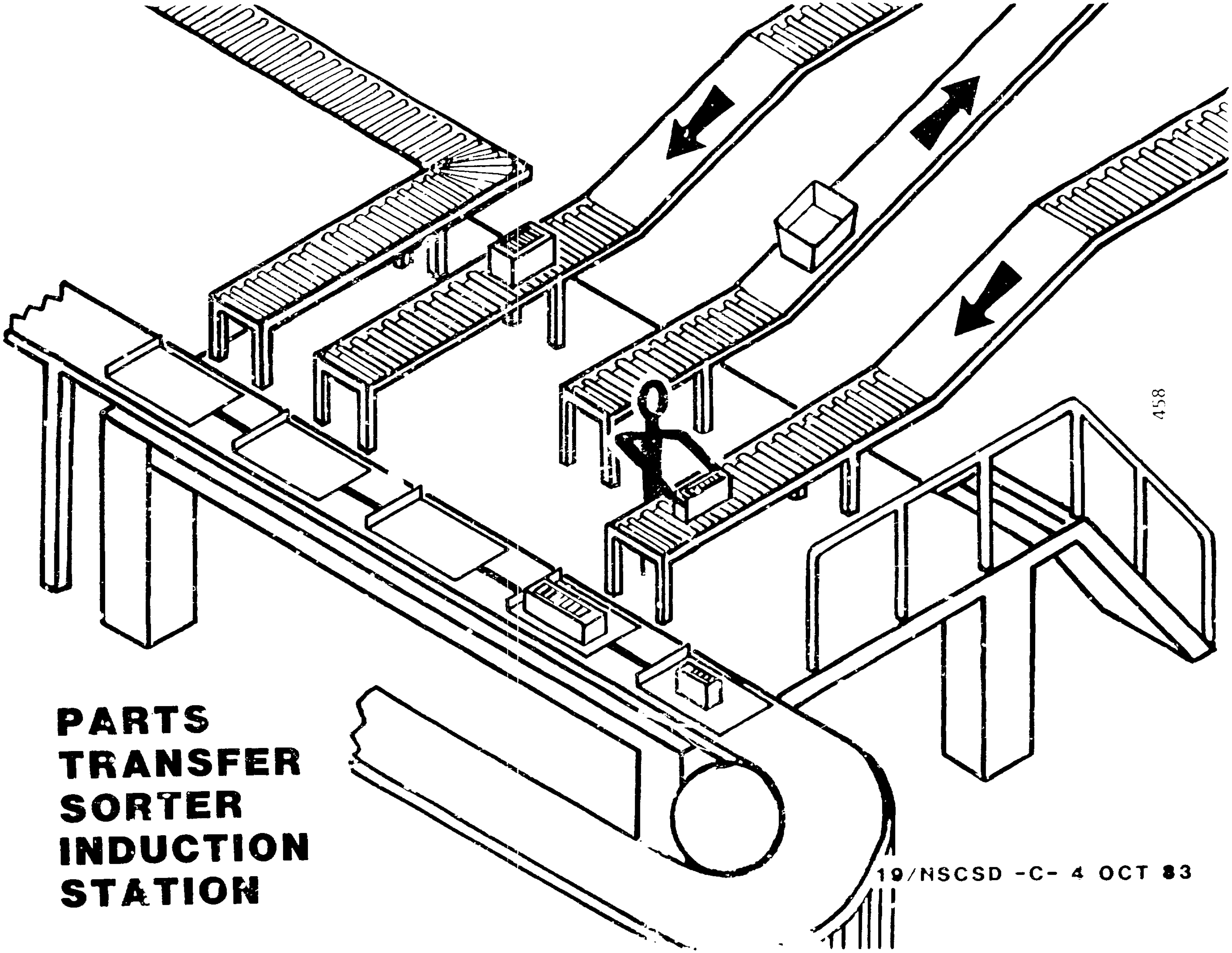
PARTS TRANSFER SORTER INDUCTION STATION

19/NSCSD -C- 4 OCT 83



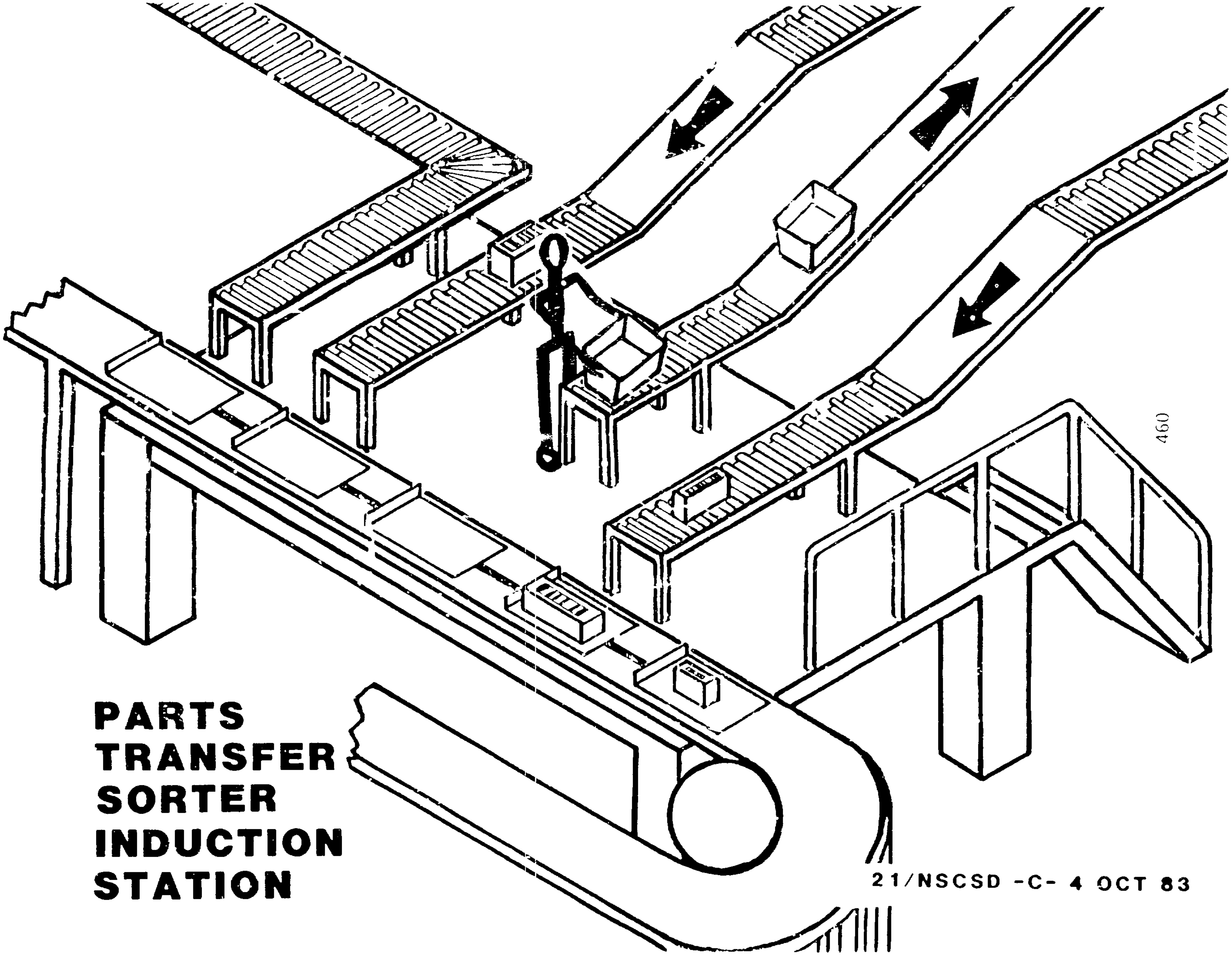
PARTS TRANSFER SORTER INDUCTION STATION

20/NSCSD -C- 4 OCT 83



PARTS TRANSFER SORTER INDUCTION STATION

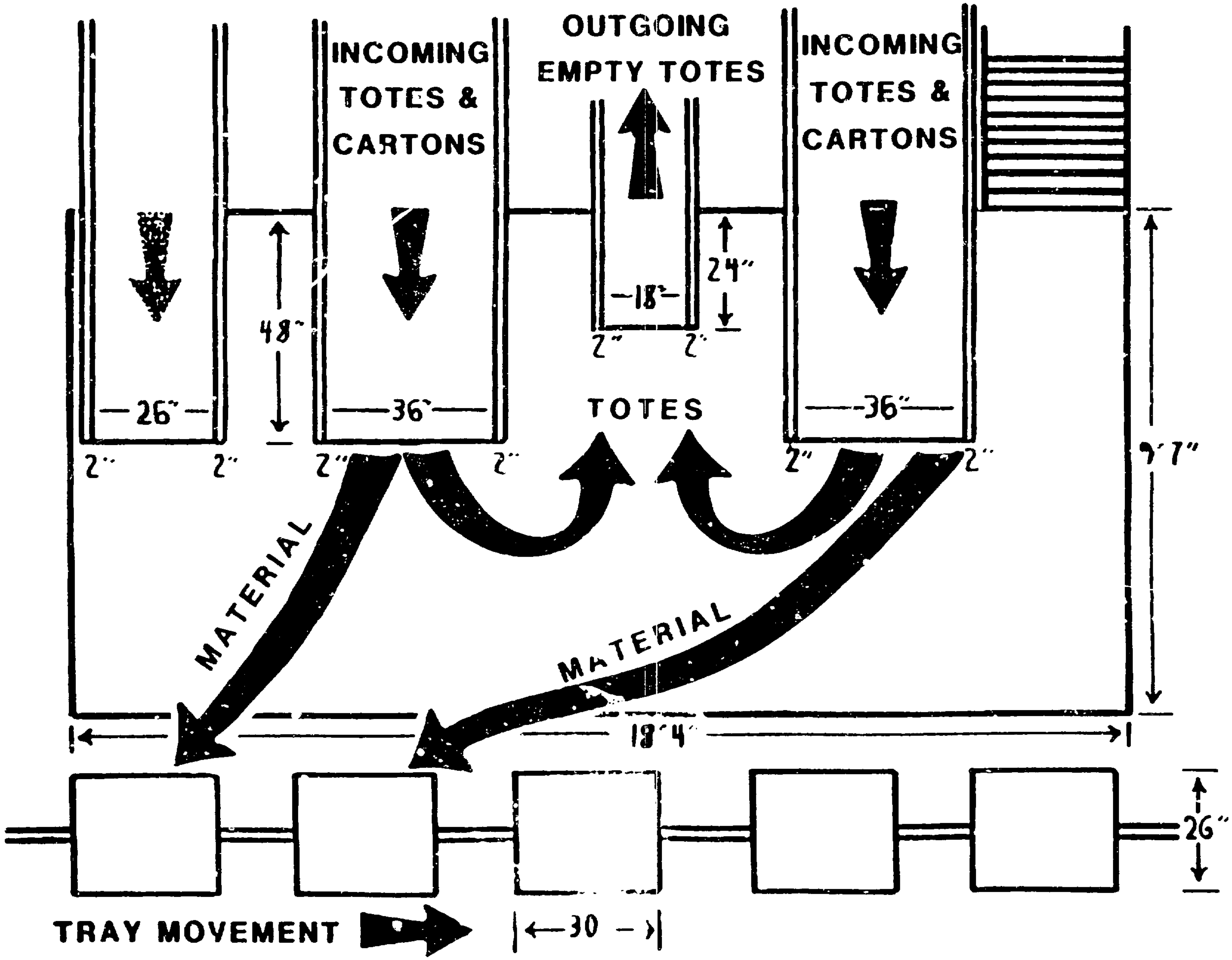
19/NSCSD -C- 4 OCT 83



PARTS TRANSFER SORTER INDUCTION STATION

21/NSCSD -C- 4 OCT 83

SORTER INDUCTION STATION



22/NSCSD -C- 4 OCT 83

--ABSTRACT--

ROBOTICS-AIDED SPARE PARTS MANUFACTURING PLANS

By: Dr. R. Elwood

Naval Supply Systems Command

Dr. Elwood spoke of the Parts-on-Demand program currently being developed by the Naval Sea Systems Command. This program is designed to develop extremely flexible automation configurations to support production of families of hard-to-obtain parts.

There are two major problems driving this program: (1) the reluctance of Congress to fund politically unglamorous logistics requirements; and (2) the diminishing numbers of supply sources in the defense industrial base. These factors have combined to pressure the Navy Supply System to develop flexible manufacturing cells to produce small quantities of high unit cost spare parts "on demand". The Navy manages 2.1 million components. Only 20% of these are reoccurring maintenance items which can be routinely scheduled for production and reorder. The other 80% are low quantity, low demand items but often of critical importance to mission accomplishment. Further, the turnover in this "80 per cent" is 15% annually, but it seems to be a randomly composed 15%, not predictable from year to year. Warehouse space is at a premium, and new systems are being procured at an accelerated rate. Hence, a consortium composed of the Naval Material Command, the Office of Naval Research, and the Supply Corps logistics research arm (located at Naval Supply Systems Command Headquarters) have developed a "parts-on-demand" program, whose goal is to produce a part 65% of the time on site or 85% of the time somewhere in the system. The current average wait time is 25 days; the average back order time for a part not in the system is 130 days; the back order time for a mission critical system, however, may run to nearly 600 days.

The latter fact causes the supply system to stock inordinately high and costly levels of inventory to meet mission essential requirements. The range of inventory technology goes from systems produced in the 1940's to the latest weapons and weapons platforms.

An NBS/Navy joint project currently is putting together a flexible parts machining cell. Other joint projects include: (1) near-net shape processing using powder metallurgy, casting, and forging; (2) off line robotics; and (3) assembly systems. Some expert system (AI) work will be done as parts/process data and generic processes are developed. Thus, the ultimate long term program objective is to "stock parts electronically". The short term program objective is to get the highest possible early payoff from the following areas of effort: (1) machining of parts; (2) electrical assembly; (3) mechanical assembly; and (4) electronics emulation or substitution.

--ABSTRACT--

ROBOTICS APPLICATIONS IN THE NAVY PUBLIC WORKS CENTERS

By: G. Meier

Naval Facilities Engineering Command

Robotics applications in the eight Navy public works centers are not easy to find. Nevertheless, there are special problems which may appropriately be attacked by the instruments of automation. Unfortunately, building maintenance and update and vehicle and navy base asset support involve many labor-intensive operations, most of which are designed to be accomplished manually. However, one such area of potential application is in sewer maintenance and cleanup.

Funds are critically low for modernization of the public works facilities. Thus, robotics projects must complete on a payback basis with technologies of lesser potential but easier adaptability. The speaker closed by asking for help from private industry in defining and promoting applications of high technology in the Navy public works centers.

POTENTIAL APPLICATION OF ROBOTICS AND STATE-OF-THE ART END EFFECTORS

LETTERKENNY ARMY DEPOT

JERRY NITTERHOUSE/STEVEN KALABOKES

Abstract

Letterkenny Army Depot has targeted areas for potential automation in the intermediate term ~~utilizing~~ robotics. ~~The~~ areas of consideration include the engraving and the camouflage painting area. Also in future plans is to interface a high technology end effector with a currently planned robotics system. The area in mind is the agricultural blast cleaning operation where planning efforts are directed at replacing the agricultural blast nozzle with a prototype cavitation water jet cleaning and effector. This paper ~~will~~ briefly describes the current method of operation in these areas and plans and limitations for robotics applications.

ENGRAVING OPERATION

Process Description

The engraving operation is labor intensive and very tedious. It requires highly skilled individuals to effectively perform the engraving procedure, skills whose transferrence to other personnel is very difficult and time consuming. The skill required approximately five years of on-the-job training for the current operator to attain the highly competent level of talent that he currently possesses.

Currently, two engraving machines are utilized; one a Gorton Model 3L with 2 and 3 directional machining and a 2:1 lettersize engraving ratio with a 19" X 7" table; the other a Gorton Model P23 with 3 directional machining capability and a 2.5-8.3:1 lettersize engraving ratio and a 6" X 16" table. Two employees are required, one a full time employee, the other a part-time employee (approximately 10 hours per week). A large stock of complex pattern and alphanumeric dies and cutting tool assortments is required to process fiberglass, bacolite and phaniculite (plastics), nonferrous and ferrous materials. Cutting tools (diamond, carbide, tungsten carbide, and high speed steel) must frequently be changed to process these materials. Pattern and character dies must be set up for each different work order received. The average set up time is 30 to 45 minutes which results in excessive nonproductive time.

Typically instrument panels, nomenclature plates and tags, control knobs, identification plates and items requiring consecutive serialization must be processed. In many instances, conventional engraving must be repeated after instrument panels and similar items have been repainted. Because the conventional engraving machines are incapable of storing and retrieving pre-programmed instructions, much time is lost in resetting character dies and fixturing to process a given work item. Other deficiencies inherent in the conventional process include restrictive character size reduction, the inability to satisfactorily engrave hardened steel and ceramics, the inability to engrave delicate objects/materials due to the clamping requirements of the process, and the requirement of index heads and rotary tables for circular and peripheral engraving tasks. Furthermore, from a human factors standpoint, the operation requiring the use of both hands is tedious and much stooping is involved.

POTENTIAL FOR ROBOTICS TO BE INTERFACED WITH THE LASER ENGRAVING OPERATION

The utilization of a robotized laser engraving operation would highly increase the efficiency of the operation and would reduce process requirements to a one man operation. Computerized laser engravers on the market are limited to a circular writing field of 3.2 to 3.9 inches. The application of the dual technologies, computerized laser engraving and robotics, to the genesis of a single machine tool would expand the work envelope of the laser to a 24" X 24" field which is compatible with the existing and projected work requirements at Letterkenny.

One great advantage of the utilization of lasers to perform the engraving task is the elimination of cutting tool requirements and cutting fluids which also affects set up time (tool replacement and replenishment). Another advantage is the ease of set up and extension of engraving operations to delicate materials since secure clamping would no longer be necessitated. The table would be fitted with dowel pins and hard stops for the reference location of the items requiring engraving. The quality of the engraved items would be enhanced, a repeatability of .01 inch is not uncommon, and would not be dependent upon the skill or mood of the operator. Skill requirements for the operation would be virtually eliminated; minimal training would be required for the operation of the machine tool. The programmability of the operation would negate the requirements of setting up dies again reducing set up time. Early projections show that a 60 percent gain in productivity would be realized as a result of applying this method. Finally, lasers can be exploited for use in other areas such as cutting stencils, numeric coding of heat shrink sleeves, wire, electronic components, connectors and generally as an alternative to the silk screening process.

One limitation of the proposed system is the .005 inch cutting depth capability. It is anticipated that some conventional engraving will be required due to this limitation. Current plans include interfacting live spindle tooling with the robot. The robot manipulator will be equipped with fastener level hard tooling interfaces to accept the laser and standard live spindle engraving heads. Special modular fixturing provisions would be interfaced with these jobs.

CAMOUFLAGE PAINTING

CURRENT PROCESS DESCRIPTION

The current process requires 1-2 workers per 8 hour shift, 2 shifts per day depending on the workload. The process is highly labor intensive and requires respirators to insure that the worker is not overcome by fumes. During the summer months, this creates a discomfort to personnel and results in excessive unproductive time due to frequent worker breaks.

There are two methods employed. The first is the projection method which involves the usage of an overhead projector and transparencies of the end item with one of eight patterns superimposed on the work piece. The transparency is then projected upon the work piece and the painter traces the pattern image projected by the overhead.

There are problems relating to repeatability associated with this method. Unless the overhead projector is positioned perfectly, the pattern will not be applied consistently. In such an event, a corrected pattern is painted over the pattern traced incorrectly resulting in a non-uniform coating. Other related problems include difficulty in projecting on the top surface of the work item and other areas which are not accessible to the projection of the transparency where impediments exist.

The second method is completely manual. The method involves reviewing Military standards and specifications and Depot Maintenance Work Requirements to determine the application of the pattern. Reference points on the work item are

utilized to determine the exact location of the pattern. Some degree of complexity is involved in painting the pattern. Although experience with a particular pattern on a particular work item produces a fairly efficient and consistent employee, changing mission and personnel make this method impractical and time consuming.

POTENTIAL APPLICATION OF ROBOTICS

Although Letterkenny seeks an improved method to replace current operations and feels that robotics may in time provide the answer, the utilization of robotics has not yet been seriously considered. Reasons behind this stance stem from the current lack of availability of a sufficient work envelope and lack of continuity of paint application to the work item surface with robots currently on the market. Current painting robots are mounted on pedestals and either multiple units would have to be utilized or an x-ray table would have to be integrated with the system to extend the work range of a single unit. The major concern is that patterns painted in either of these models would not repeatably match up. Another concern is the incidence of significance overspray which may result in repeated rejections of completed work item. Furthermore, floor space limitations again loom due to the process occurring in a self contained area. Finally, many different colors are involved which imply flushing problems.

What is needed to effectively camouflage paint existing and projected work items is a gantry level system robot with sufficient dexterity to effectively coat all surface areas of the work item. Since painting is an art and is largely dependent upon the skills of the painter, a lead-through teaching mode is imperative.

CAVITATION WATER JET END EFFECTOR

The cavitation water jet cleaning method has been considered to potentially replace the planned agricultural blast cleaning end effector. The system is highly experimental and is being developed by Daedalean Association, Inc. Not much is known about the process other than it is a technology that utilizes a turbulent high pressure stream of water to remove soft materials such as paint and rubber from hard surfaces. The principle is based on pressure differentials which literally lift paint from the surface of the work item resulting in a much more efficient means of paint removal; abrasive particles clinging to the work surface is eliminated and coating clinging to pitted areas are removed without reprocessing requirements.

Other advantages which may result from utilizing this technology as a replacement to agricultural blast cleaning include:

(1) Reduced robot arm loadings

(2) Reliable supply of cleaning media; water is recycled

(3) Elimination of potentially explosive aerosols

(4) Reduction in the volume of waste products

(5) Reduced blast media costs

(6) Higher quality

CONCLUSION

With further technological advancement in the robotics industry, Letterkenny could surely benefit in the areas cited above. Letterkenny is dedicated to reduce operating costs, improve the quality of the end items serviced and improve the industrial base to insure readiness for our nation's defenses.

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--ABSTRACT--

ENGINEERING FEASIBILITY AND ECONOMIC CONSIDERATIONS OF ROBOTICS APPLICATIONS - WELDING, PAINTING, ETC., AT SACRAMENTO ARMY DEPOT

By: E. Helalian

Sacramento Army Depot

Major application projects at Sacramento turn on economic considerations. In the welding shop, a cost/payback model has been developed to ease the comparison of competing alternatives and provide a comparison with the present method. The results yielded by the model when applied to the current arc welding process indicate that savings accrue whenever a lot size exceeding twenty parts is processed. The payoff period for a robotics welding investment at current volume of work is approximately one year. Two specific parts were chosen for the model analysis. Details of the welding analysis were provided by the speaker, including a step-by-step process analysis with concurrent economics. The PUMA 750 and the T3-726 were used in exercision of the model. Weld speeds three times that of manual welding (10 inches/minute) were assumed in the analysis. These assumptions have been verified by private industry in test runs in similar conditions.

A painting booth robotics application was also described by the speaker, as was an engraving application. No economic models were provided by the speaker for these two applications.

CURRENT ROBOTICS PROJECTS

RED RIVER ARMY DEPOT

WALTER OOSTERVEEN

ROBOTIC WELDING SYSTEM FOR M113 SUSPENSION

(On-Going Project)

A two-step procurement action was initiated by RRAD about Dec 82. This proposal contained our requirements for a system that would weld the hull robotically after all necessary components had been tackwelded in place. We stipulated that the robotic welding was to be accomplished by 3 robots welding simultaneously and that the time in the welding station was to be accomplished in 2 hours.

Kohol Systems, Inc., was the successful bidder. Delivery of the system should be Dec 83 with an operational date of March 1984. The system will operate in the following sequence after the hull has been prepared for the welding station by having all the necessary items tack-welded in place:

1. The hull will be located in a specifically prepared fixture in the welding station.

2. One operator will control the entire weld cycle of all 3 robots.

3. The 3 robots will start their pre-programmed welding cycles simultaneously. The robotic welders will alternate welding inside and outside of the idler mounting plates to reduce heat build-up.

4. A typical sequence would be for the left side robot to weld on the outside of the left idler mounting plate, then weld on the left side plug holes. Return for additional passes on the idler plate, then another series of plug holes. One of the alternate passes will be to weld the bumper plate.

5. The rear robot will alternate welds on the inside left and right idler plate and on the outside stiffeners.

6. The right side robot will be welding a similar path on the right side.

7. At the completion of the three weld programs, the robots retract to a home position. The hull is removed from the weld station to permit another to enter.

This system will consist of 3 Cincinnati Milacron T3-746 robots, 3 Miller Pulstar 450 Welders with cobramatic push-pull wire feeders and MIG water cooled welding torches, each robot will have a probe style seam tracker for weld path tracking, and there will be one master control station. Safety will require a heavy duty wire mesh enclosure around the welding station.

This system will meet OSHA Safety Standards and will reduce the overall welding time by 6 hours.

SINGLE PIN TRACK DENUDE AND DISASSEMBLY SYSTEM
(On-Going Project)

A two-step procurement action was initiated by RRAD in Sep 82. This proposal outlined our requirements for a system that would take a roll of single pin track which has been placed in a hopper, and uncoil the roll onto a conveyor. The track is now conveyed into a denuding chamber. This denuding chamber was to use high pressure water and through this means the rubber was to be removed from the inner side of the track (the inner side being the side that rides on the roadwheel). Also, in this chamber one sidse of the track pin must be cleaned. This cleaning removes any debris which might be imbedded around the nut which secures the track pin. The track remains in this cleaning position for 1/1/2 minutes. This is the governing time for the remainder of the operations as it proceeds from station to station. The next station is outside the denuding station. A pneumatic torque wrench comes down and removes the nut which holds the track pad in place. The pad is pushed out and falls onto a conveyor which in turn moves the pad into a container. The nut is dropped into a chute which in turn goes to a container. At this station a pneumatic torque wrench comes in from the side and removes the nut off the track pin and deposits the nut in a chute which goes to a container. The track is now moved to the next station where a clamp will come down and hold down the track shoe. A hydraulic ram will come in from the side and push the track pin out. At the same time another hydraulic ram pushes the bushings out of the track shoe. The shoe is now a separate entity and proceeds down the conveyor to the end of the line. At this point a robot with a magnetic pick-up block will pick up the denude disassembled shoe and stacks it on a pallet.

The successful bidder was Cincinatti Milacron. The system will consist of two separate robots, a T3-7267 and a T3-746. The M26 was to be used in the denuding chamber and the 746 to be used for stacking the track shoes. The water-jet system is manfufactured by Aqua-Dyne.

The current method of disassembly and denuding takes 3.8 minutes each where this method will average out at 2 minutes each. At this rate, the system will amortize out in 2.35 years.

This method is in compliance with OSHA Standards and completely eliminates the current hazardous method of vapors and pollutants which arise from the salt vats.

DOUBLE PIN TRACK DENUDE AND DISASSEMBLY SYSTEM
(On-Going Project)

RRAD is in the process of awarding a contract to the lowest bidder for the development of a system which will remove the rubber from the track shoes and completely disassemble the track. The cost of this project will be $990,000.

The system will be configured as follows:

1. The track will be placed in an enclosure where it will be unbanded and the lead track shoe will be engaged in such a manner that the roll will be uncoiled onto a conveyor which feeds the denuding chamber.

2. Once inside the chamber, the rubber will be removed with high-pressure waterjet being directed by a robot. The debris which is normally found around the end connectors and the center guide will also be removed at this time. This cycle will be of four (4) minutes duration and the governing factor in the new time element.

3. The denuded track progresses to the next station where the end connector and center guide nuts are removed. The tee bolt and center grouser will also be removed and placed on a conveyor which deposits them in separate containers.

4. The next station will remove the end connectors. When the end connectors are removed, the track shoe assembly is now an individual item.

5. The track shoe assembly is conveyed to the next station where it is rigidly clamped and the pins are pushed out. The pins will drop onto a conveyor which leads to a container.

6. The denuded and disassembled inserts will be picked up by a robot and stacked into a container.

The system shall include a filtration system capable of separating rubber particles and debris emanating from the track. Currently the waste water will be going into the depot drainage system, therefore, the requirements are for an 8 micron filtration system.

This system when operational will have an average time per assembly of 4 minutes. It will also eliminate the hazardous health conditions now existing and it will meet OSHA requirements both for safety and noise.

ROBOTIC CAMOUFLAGE PAINTING ON M113 FOV
(Future)

Camouflage painting whether performed by the field or the rebuild depot is a slow and tedious task. In fact, TB43-0209 has an estimated total manhour time of 20 to camouflage one (1) M113 vehicle. RRAD has been informed that sometime in FY 84 they will start camoufaige painting of the M113 vehicle. With this in mind, we turned our thoughts to the use of robots.

A robot can be taught to paint in a particular pattern and it will repeat this pattern until it gets cancelled out. Also, a robotic painting unit is capable of spray painting more than one paint color and camouflage painting requires four (4) colors.

The project will consist of three (3) hand teach type robots mounted on telescoping platforms, travelling on a rail and controlled by one (1) master controller.

The vehicle would be driven over a pit to a designated spot. One (1) robot would be mounted on a telescoping platform in the pit. This robot would paint the front, undercarriage, and the rear of the hull. On either side, a robot mounted on a telescoping platform will paint the side and reach over the top to paint its

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respective half of the top. Because the platforms will be on rails, they will travel the full length of the hull. The master control will have the capability of either allowing the robots to work independently or simultaneously. After painting, the vehicle is moved into an infra-red tunnel to be cured.

It has been estimated that camouflage painting of the vehicle can be accomplished in 2 hours.

AD-P004 016

Field Applications for Robotic Materiel Handling

Tooele Army Depot

Fred Eldredge

I will present a description of interests and activities involved in the utilization of robotics and allied technologies for Army field applications in materiel handling roles. This presentation ~~will~~ encompass:

~~a.~~ Motivators for ~~utilizing~~ using robotic technology in this new context;
~~b.~~ Similarities and differences between technology required for robots used in industry and those of interest for field roles;
~~c.~~ A description of some of the Army groups with charters in the robotics research and development areas; and
~~d.~~ A description of two materiel handling, field oriented, robotics demonstration systems.

The principal motivator for the use of robotic technology within these application areas is directly related to manpower. If one addresses applications such as minefield clearing and reconnaissance, concerns over personnel exposure to a hostile environment are paramount. Less obvious benefits may accrue from improvements in soldier effectiveness i.e. by utilizing robots to augment soldiers in tasks such as ammunition handling, overall unit and individual effectiveness may improve and provide a net gain in security. Examination of expenditures associated with acquisition and operation of major weapons systems indicates that expenses associated with manpower, e.g. training, are a major element in overall system cost. Application of robotics within these systems may offer specific cost and performance advantages. One valuable characteristic of robotics in this context is the potential to utilize the flexible characteristics of the equipment to enable adaptation for use in systems which were not originally designed to incorporate robotics. This process generally known as "product improvement" when utilizing more conventional technologies can reduce the time necessary to move equipment with significantly enhanced capabilities into the inventory. Assessment of opportunities to insert this technology into a military field environment must take into account:

a. Initial system costs;
b. Reliability and maintainability considerations, and;
c. Overall impact on system effectiveness

To summarize, robotic systems may be capable of contributing to more effective use of limited troop resources by:

a. Replacement of soldiers in some structural tasks, and;
b. By enabling soldiers to perform more efficiently through augmentation by robotic devices.

In light of the above discussion a number of similarities and differences between field and industrial uses for robotic technology become evident. Industrial and field oriented applications for robotic technology bear the closest resemblance in the materiel handling role. The Army has extremely large stocks of a wide range of materiel items in storage. The ability to utilize the flexibility and reprogramability of robotic devices to effectively interface with these large inventories are key features arguing for the development of these systems. These materiel items vary over a wide range of weights and configurations necessitating flexible manipulators and requiring the development of a variety of end effectors or grippers. The same robotic characteristics which make possible rapid

reprogramming in batch manufacturing operations will be of significant benefit in applications which require field reprogramming. There are obvious similarities in the hostile environment application motivators as well, although the environments are quite different. Other similarities exist in concerns with system cost and RAM. Operator safety considerations also extend into the field application sector but current industrial perimeter safety systems do not appear to have much direct transfer potential to field roles.

Critical environmental considerations for field applications can be subdivided into two principal areas:

a. Lack of a partially constrained work place, and;
b. Wide variations in temperature, humidity etc, and exposure to rain, dust, salt spray, etc.

In equipment design terms, requirements for transport of field systems will impose a number of system weight and power consumption limitations. Increases in payload to weight ratio of an order of magnitude of more will be required.

Developing systems hardened to the field environment can be accomplished by the application of existing technical approaches common to avionics, construction equipment etc.

If one examines the likely requirements of most Army oriented field applications while bearing in mind projections for the sophistication or robotic systems, one conclusion is inevitible. The great majority of robots working in field applications for the forseeable future will require frequent or constant interaction with their human operators. The issue of human-robot interface is likely to have its most specific impact in the following areas:

a. Safety;
b. Human-robot task allocations;
c. Programming (teaching);
d. Operational accommodation to unexpected contingencies e.g. unable to identify part;
e. Maintenance operations, and;
f. Personnel training.

A DARCOM-TRADOC AI/Robotics Steering group has been formed to coordinate the activities of the Army's principal materiel development agency DARCOM and the training and doctrine command TRADOC. The Corps of Engineers Engineer Topogrphical Research Lab has the role of lead agency for the Army in the AI/Robotics area while the Human Engineering Laboratory and Soldier Support Center have the lead roles for DARCOM and TRADOC respectively. Within DARCOM a separate lead agency for artificial intelligence exists. This agency is the Army Reasearch Office or ARO.

In the materiel handling sector two field oriented materiel handling robotics demonstration projects are of interest.

The first of these, the Robotic Ammunition Loading System, was initiated in 1981 by the Human Engieering Lab with major support from Depot System Command's Tooele Army Depot. The goal of this project is the investigation of the applicability of industrial robot technology (but not industrial robots themselves) to Army field applications.

Goals of the project are the use of off-the-shelf robotic equipment to obtain an early appreciation of the potential for future militarized robotic systems to impact the following areas:

1. Manpower augmentation
2. Operational capabilities in field environments, and;
3. Product improvements to existing equipment.

An early decision was made to focus the demonstration effort on selected material handling tasks which are associated with an M110A-2 8" howitzer.

Selection of off-the-shelf equipment was mandated by program dollar and time constraints. Funding for the project has come entirely from HEL in Lab Independent Research funds and this coupled with an Aug 1983 milestone for the first formal system demonstration necessitated the use of readily available hardware.

Major system components include:

Unimate 4000 robot
PUMA 760 rbot
Digital Equipment Corporation PDP 11/23 computer.
A Hofmann environmental enclosure with onboard refrigeration and a variety of power sources and hard automated systems with which the system interfaces.

A 40 foot trailer with air-ride suspension and a weatherproof enclosure houses the system for transportation purposes and essentially provides an area of floorspace comparable to that found in a factory for the first generation Phase I demonstrator.

The Phase I operational sequence will proceed as follows. Ammunition will be uploaded from pallets located in a truck parked in a previously determined location within the work envelope of the large robot manipulator, pallets of ammunition in the bed of the truck will have previously been placed intact into a jigging device that will simultaneously position and support the pallets of projectile essentially creating a matrix of positions which when the truck appropriately positioned will place the projectile nose plugs in previously determined positioned. The pentalties paid for the lack of sensor technology in Phase I are evident in the absolute dependence on previously programmed projectile locations and the complexity of the first of two gripper systems which must acquire projectiles by the unoriented nose plugs. Once the projectile has been acquired, it will be placed in a rack and its type, location and lot number will be stored in the memory of the PDP 11/23. On demand the system operator will call for a specific projectile/fuze combination and the 4000 robot will remove the projectile from the rack position, place it in a clamping fixture and break the nose plug loose. The Puma 760 will be used for noseplug removal, fuze acquisition, fuze insertion and torqueing. At this point in the operation a second gripper system mounted perpendicular to the first on the 4000 will be used to acquire the projectile from the side, for transfer to the previously positioned howitzer loading tray.

The principal areas of technology transfer to future field oriented robotic systems include:

a. Integration of sensor systems viable for field applications with robot controllers;
b. Operator interface e.g. safety systems for field applications;
c. Approaches to high power to weight ratio manipulators, and;
d. Workpiece acquisition on rough terrain.

A second demonstration system is a component of the Ammunition Input Module which is in turn a component of a larger conceptual system (BRASS 2000 an acronym for Battlefield Robotic Ammunition Supply System) for modernizing the conventional ammunition supply system. This concept embodies doctrine and technologies involved in:

a. Packaging, handling, and transportation;
b. Computer automation and communication, and;
c. Robotics/smart materiel handling equipment.

This concept has evolved from a joint project of the HEL and Missile Munitions Center and School.

In summary, I believe the technology development necessary for successful military field application of robotics will have positive transfer to a wide range of applications in the civil sector. Developments associated with higher power to weight ratio manipulators (to include use of improved materials and design techniques) will have direct ramifications for field use but can also enable higher manipulator velocities which may boost cyclic rates for civil operations such as assembly. Transfer potential is obvious in such areas as power efficient actuators and interactive safety systems. I recall that in the 11th ISIR held in Tokyo a number of speakers voiced interest in future application of robotic systems in mining, forestry, and oceanographic enterprises. In my view there is a high probability that research and systems integration work associated with field application of materiel handling robotic systems will serve a dual role. First as a contributor to national security, and secondly as an enabling force for a wide range of civil applications in both the factory of the future and new applications for robotic systems in field settings.

GAGE BLOCK CALIBRATION

by
Dean Shimek
Navy Gage and Standards Center
Pomona California

We render calibration service to world wide activities. Our gage block standards, transfer standards, are calibrated interferometrically in house annually and are also calibrated at the National Bureau of Standards, thus assuring traceability to NBS.

When we receive gage blocks they are first cleaned ultrasonically in a Freon bath and checked for flatness and parallelism by technicians manually. Each block is wrung to a quartz optical flat to determine the degree to which the block is flat and parallel. The technician also observes the quality of the surface finish and checks for nicks and burrs. This inspection is done manually. If a block appears to be in bad shape its flatness and parallelism is measured to millionths of an inch under an optical comparator.

The actual length calibration sequence is done in an isolated room by means of an electromechanical comparator which can resolve 1/10 of one millionth of an inch. The comparator is essentially a mechanical caliper which incrementally cams down on command from the operator.

Before the blocks are measured they are stabilized at ambient conditions of 68°F for 8 hours on aluminum soaking plates beside our standard block sets. The calibration sequence involves comparing the length of each customer block to the length of the standard block and thus determining the deviation of the block from nominal. We attain an accuracy at 4 inches ± 4 inch/inch of length. The measurement task is tedious and repetitive and quickly leads to operator fatigue, proneness to error, and a high rate of employee turnover. Each block is measured at three or four separated points after the machine has measured our transfer standard. When a person repeats this through a 121 or 88 piece set of blocks boredom quickly sets in. Thus we feel we need a pick and plan robot to handle the blocks and control the comparator. A cost and feasibility study is underway to identify engineering concepts for the complete automation of the calibration sequence.

Ideally in the future it would certainly simplify our system if we could have the robotic gripper do the measuring, thus combining our comparator and robot manipulator functions to completely automate the calibration sequence.

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